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Importing the Vernacular: An Analysis of the Panama Houses of the Former Charleston Navy Yard as an Adapted Regional Building Typology

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IMPORTING THE VERNACULAR:
AN ANALYSIS OF THE PANAMA HOUSES OF THE FORMER CHARLESTON NAVY YARD AS AN ADAPTED REGIONAL BUILDING TYPOLOGY

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by
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ABSTRACT

Military architectural designs are often overlooked in vernacular architecture due to the widespread use of standardized plans at military installations. However, factors including climate in certain regions force the development of new designs for military bases that are better suited to local conditions. This is arguably the case for the Panama Houses of the former Charleston Navy Yard, which are an example of a vernacular building type imported from a foreign context. While scholars have looked from a broad perspective at the Navy Yard and the more prominent structures, no study has been completed considering the history and form of the Panama House. Bringing together architectural evidence from this group of buildings and U.S housing in the former Panama Canal Zone, this study explores the origins of the Panama House and the factors that brought it to Charleston, ultimately positioning this vernacular form within the context of the region and United States military installations.

DEDICATION

To my parents, brothers and sister for their steadfast love and support over the last two years. Your words of encouragement helped me through this process.

ACKNOWLEDGMENTS

This work would not have been possible without the advice and support of my thesis committee: Amalia Leifeste, Brent Fortenberry, and Carter Hudgins. Your comments, questions and advice allowed me to develop my topic and keep my research and writing headed in the right direction. Thanks also go to Don Compagna for providing me with help and guidance in my research and for his invaluable knowledge of the history of the Navy Yard; and thanks to Lisa Reynolds for allowing me to access the Panama Houses at the Charleston Navy Yard. I would also like to thank Craig Bennett, Jr. for his support throughout this process over the last year.

TABLE OF CONTENTS

Table of Contents (Continued)

Page

Table of Contents (Continued)

Page

LIST OF FIGURES

List of Figures (Continued)

Figure Page

List of Figures (Continued)

Figure Page

List of Figures (Continued)

Figure Page

List of Figures (Continued)

List of Figures (Continued)

Figure | Page

List of Figures (Continued)

Figure Page

List of Figures (Continued)

Figure Page

List of Figures (Continued)

Figure Page

List of Figures (Continued)

Figure Page

List of Figures (Continued)

Figure Page

List of Figures (Continued)

Figure Page

CHAPTER ONE:

INTRODUCTION

Overview

During the 1930s, the Charleston Navy Yard underwent a period of expansion during which some of the most architecturally intriguing and significant buildings on the property were constructed. A group of these buildings, known locally as 'Panama Houses' due to their distinct form drawn from U.S. housing in the Panama Canal Zone, was constructed beginning in 1937 as officers' quarters south of Noisette Creek along the Cooper River at the northern end of the base. Despite their distinct form and importance as a vernacular building type, the Panama Houses have not received full attention from scholars. Little primary source material exists on this group of buildings. What little information that can be found is in the form of historic photographs, Navy Yard assessments completed during the period of base closure, and a National Register nomination for the district. This information, however limited, remains useful in tracing the roots and evolution of the Panama House design in order to tie it back to the vernacular architectural form of military housing in the Panama Canal Zone.

Vernacular architectural types are regional expressions that result from a variety of factors, among them are cultural forms known to a region or people, available materials, building traditions and environmental adaptation. On occasion, examples of vernacular forms are taken from their native region and altered and adapted to make them a new architectural expression before they are dropped into a new setting. Adaptation of an existing vernacular form and its importation into a different region makes it a new vernacular form for the region into which it is ported. This thesis studies the Panama House as an imported vernacular building type by looking at the factors that led to the adoption of its design in Charleston, mainly focusing on the use of the design as a climatic adaptation in terms of its context and form.

While the subject of this study is the Charleston Navy Yard Panama Houses, it is expanded geographically with the inclusion of buildings in the Panama Canal Zone to place the Panama House design within a larger spatial context. An assessment of the range of domestic/dwelling forms of Charleston and North Charleston reveals that there are no local similar forms from which the Panama House could have evolved. Connecting the design to military housing in the Canal Zone reveals the Panama House as a product of circumstance. Experience with a building form successfully implemented for the climate of a foreign region served as a response to the circumstances of the Charleston climate. The result was the importation and adaptation of the design of the distinctive form of the Charleston Navy Yard "Panama House" as a new vernacular type in the Charleston region.[1]

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[1] The sources of U.S. Army designs for housing in the Panama Canal Zone, which include photographs, site plans, and architectural and design drawings, are located at the Library of Congress in Washington, D.C. and in the Cartographic and Architectural Records of the National Archives at College Park, Maryland. They are discussed in Chapter Six to place the Charleston design of the Panama House in context.

This study addresses fundamental questions surrounding the Panama House as a vernacular form of architecture. These questions include: What factors influenced the form of the Panama Houses in terms of their building features and organization of space? What is the connection between the design of the Charleston Panama Houses with those in the Canal Zone? To what extent did the region and climate play a role in the design and construction of the building, if at all? And how successful was the design of the Panama House in working with the environment through passive cooling to reduce interior heat? This study will answer these questions by establishing context and conducting a comprehensive analysis of the Panama House designs. The way in which the design for these buildings evolved over time was looked at closely in order to determine how changes to the structure may have affected the ability of the building design to function with the climate.

Significance

The Panama Houses comprise a group of buildings situated within the wider collection of historic resources which chronicle the establishment, growth, and development of the upper echelon of senior military housing, structures, and facilities within the Charleston Navy Yard. Of the twenty-eight properties that contribute to the historic and architectural character of the Charleston Navy Yard Officers' Quarters Historic District, there are ten Panama Houses, more than any other type of contributing structure. The Panama Houses also comprise the overwhelming majority of structures built during the Inter-War Period. Excluding Quarters J, they represent the only Quarters built at the Navy Yard during the 1930s when the yard was undergoing rapid expansion.

The first eight Panama Houses were constructed as New Deal federal projects by the Works Progress Administration (WPA) which adds to their significance since they serve as visual representations for an era of growth and economic revitalization provided by federal programs during a unique period in American history. Additionally, the design serves as an index for the changing technology and modernization of residential officers' housing utilized by the Navy and United States military. The last two Panama Houses constructed at the Navy Yard follow a design that deviates slightly from the original. This shows that the Panama House is an evolutionary building type that was implemented and adapted at the Navy Yard before the design fell out of use in favor of newer housing types. The adaptations that allowed the design to evolve are significant within such a small sample. Additionally, resulting from an interpretation of various forms and styles, and importation from a foreign context, the Charleston Panama House is a vernacular form well suited for the Charleston climate.[2] These factors make the Panama House an important component of vernacular studies and architectural history. Their continued preservation and reuse is vital to the preservation of the Charleston Navy Yard and military architecture and heritage from the first half of the twentieth century.

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2 Hampton Tucker et al., "Charleston Navy Yard Officers' Quarters Historic District," National Register of Historic Places Inventory/Nomination Form, Historic Preservation Consultants, Inc., Charleston, South Carolina, 19 January 2007.

Panama House History

Located in the landscaped area of the Officers' Quarters Historic District just north of the shipyard, the first Panama Houses were constructed during the 1930s inter-war period as part of the expansion of the navy yard prior to the start of the Second World War. This came at a time when the workload at the yard was expanding for increased production which led to a steady increase in employment prior to the war. Part of the reason that the Navy Yard was undergoing a period of revitalization and expansion was due to the implementation of Roosevelt's New Deal programs that helped bring the nation out of the depression.

The WPA, one of the federal programs implemented by the New Deal, was responsible for the construction of eight of the Panama Houses during the 1930s as a series of WPA projects. Quarters K, L, M, and N were constructed by the WPA in 1937 on the eastern edge of the district along Turnbull Avenue and Everglades Drive adjacent to the west bank of the Cooper River. These are the only buildings of the Panama House type constructed in the eastern area of the district. The remaining six Panama Houses were constructed in the western reaches. The second set of houses constructed by the WPA are Quarters O, P, Q, and R from 1937 – 1938 on Hobson Avenue. These were followed several years later in 1941 by the last two Panama Houses, Quarters S and T, the only Panama Houses to be constructed during World War Two. The initial plans for the buildings were adapted from Army Quartermaster plans for housing in the Panama Canal Zone, which is why they are known as Panama Houses.

Similar plans to the Panama House design dating from the 1910s through the 1930s are examples of housing located in the Panama Canal Zone. Although the design was brought to Charleston from the Canal Zone, a lack of evidence indicates that the design was not used anywhere else outside of the Panama Canal Zone aside from the Charleston Navy Yard. Examples of housing constructed during the same period at other Naval and military installations throughout the United States do not follow the Panama House design. The reason for why they are not built anywhere else is unclear, as the design could be applied to regions climatically similar to Panama or Charleston.

The Panama Houses retained their original use as officers' housing throughout the operation of the Navy Yard. Of the ten that exist, only two of the Panama Houses are in use today. One of the buildings, Quarters K, is used as an event venue while the other is rented as an apartment. Although two more of the buildings were used briefly as a restaurant and office for an engineering firm, today they sit empty.[3]

Architectural Description

Although they belong to the same building type, the Panama Houses can be separated into two distinct groups that reflect different periods of construction. Quarters

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[3] Tucker et al., "Charleston Navy Yard Officers' Quarters Historic District," 21.

Figure 1: *Construction of Panama Houses, 1936.* This image shows the construction of the first four Panama Houses along the Cooper River at the Charleston Navy Yard. *Image courtesy of Don Campagna and the City of North Charleston Archives.*

K through R, the houses constructed as WPA projects in 1937 and 1938, represent the first iteration of the Panama House. The second group includes Quarters S and T – the last two houses to be constructed. The primary difference between these two groups is in the design of the plan. While the layout of the top floor of both types remains largely the same, shifts in the spatial organization of the ground floor plan signify a clear change in the spatial hierarchy and circulation pattern between the two types.

Quarters K through R have common characteristics, largely evident on the exterior.

Square in plan, the Panama Houses are two stories in height. The ground floor is constructed using cast-in-place reinforced concrete columns with recessed bays constructed of four-inch hollow tile. The tile is finished with a whitewashed concrete stucco. The concrete structure for the ground floor serves to support the reinforced concrete beam and slab for the floor above. At the second level there is a shift in material from concrete to wood framing. The framing is clad with German Novelty siding painted white with dark bands of trim around the window openings and the edges of the second level. Another defining characteristic of the design is the low-pitched hipped roof with two louvered ridge vents and wide overhanging eaves with exposed rafters. The eaves feature ventilation grates that allow heat into the attic and out the ridge vents in order to increase air circulation to help cool the building. An exterior lateral stair of reinforced concrete wraps around the northwest corner of Quarters K through R. Cantilevered at the second level, the stair opens into the kitchen. The only exception is Quarters O whose exterior stair is situated at the northeast corner. All eight of the buildings feature casement windows, although the materials used differ. Casement windows used in the first four Panama Houses constructed by the WPA feature wood frames while the second group constructed from 1937 – 1938 features steel casement windows. Photographs from the construction of the first four Panama Houses indicate that the roofs of the buildings were originally finished with tile but now feature asphalt shingle. The buildings also feature a two-car garage incorporated into the first level at the rear of the house (west elevation). They were the first buildings on the base to have a garage integrated into the design.

Figure 2: *Completion of Quarters K and L, 1937.* Quarters L is in the foreground while Qaurters K is visible to the rear. *Image courtesy of Don Campagna and the City of North Charleston Archives.*

Quarters K, L, M and N are oriented so that their front façades face the river. The main façade of each building features a three bay wide screened-in porch on the ground level that also serves as the main entrance to the building (the lateral stair at the northwest corner is a secondary entrance). The second level features three bays with cantilevered windows. The central bay, with six casements, is approximately twice the size of the two flanking windows which each feature three casements.

The main entrance from the porch on the ground floor opens into the mudroom or

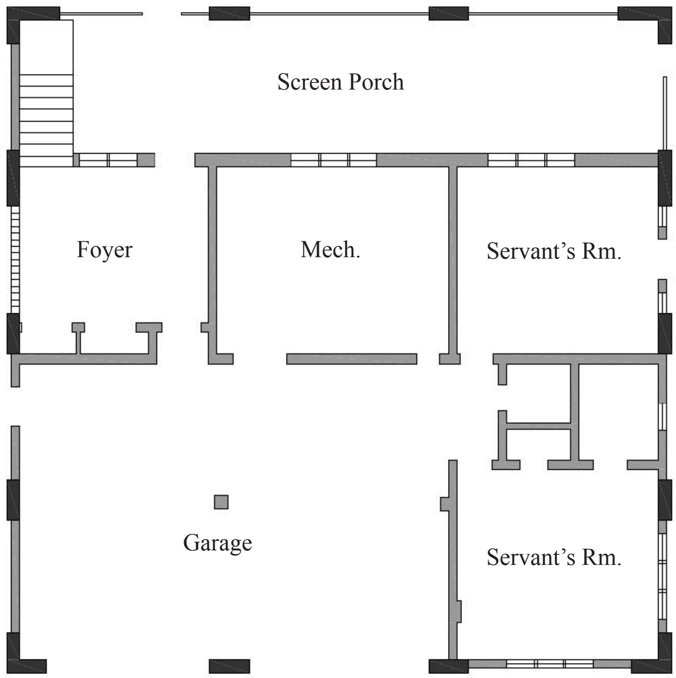

Figure 3: *Initial design of the Panama House, Ground Floor Plan.* Plan followed by Quarters K - R. *Drawing by author based off plans from the Charleston Naval Complex Redevelopment Authority (RDA).*

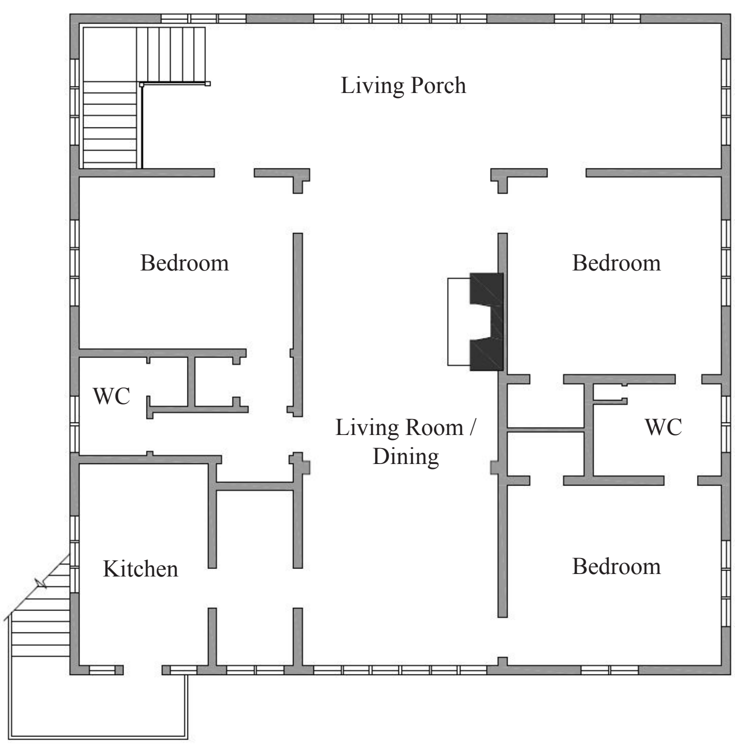

Figure 4: *Initial design of the Panama House, Second Floor Plan.* Plan followed by Quarters K - R. *Drawing by author based off plans from RDA.*

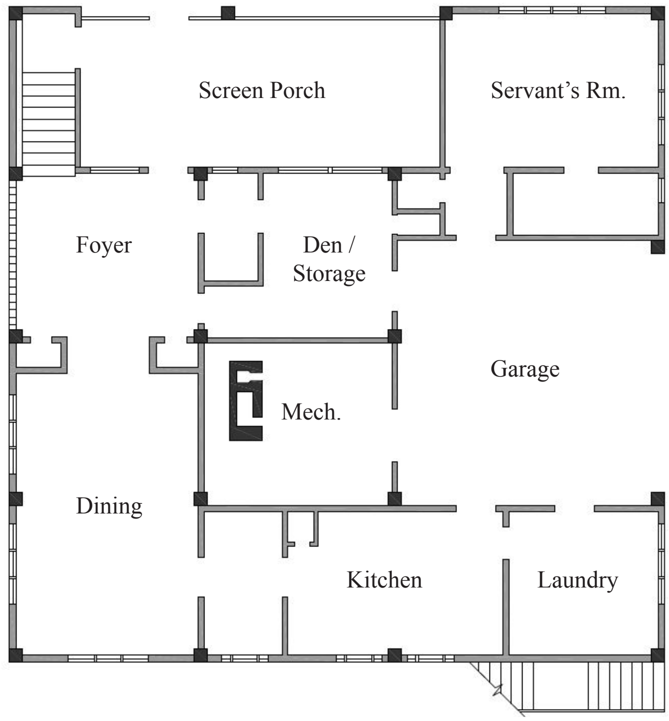

Figure 5: *Second design of the Panama House, Ground Floor Plan.* Plan followed by Quarters S and T. *Drawing by author based off plans from RDA.*

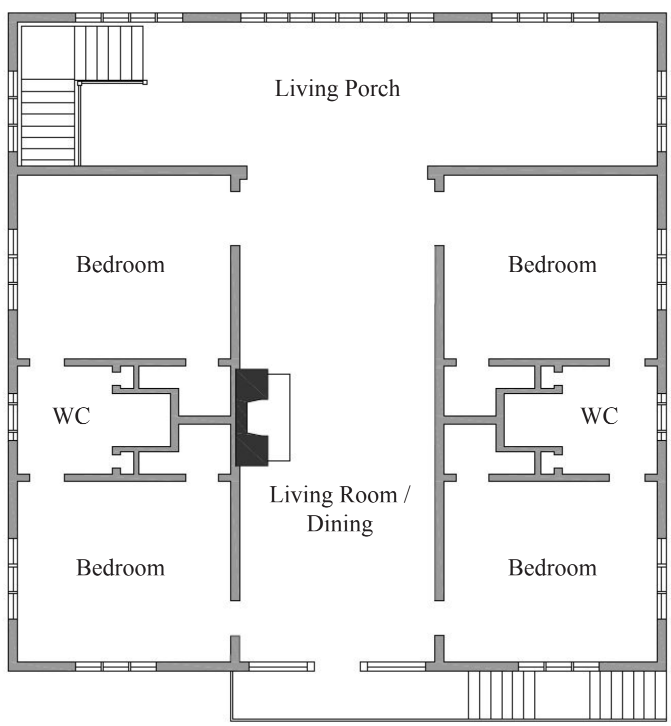

Figure 6: *Second design of the Panama House, Second Floor Plan.* Plan followed by Quarters S and T. *Drawing by author based off plans from RDA.*

foyer, located at the northeast corner of Quarters K through N. The north wall of the room is constructed of glass block to allow light into the interior. The mudroom provides access to the garage; the two rooms used as servants' quarters are accessed from the garage. From the mudroom, a stair provides access to the second floor which serves as the primary living space. The second level features a T-shaped plan. The top of the 'T', known as the "living porch" runs along the main façade of the building, the large windows providing lots of natural light into the interior. It is here that the stair from the mudroom accesses the main floor. The central portion of the 'T' runs through the center of the house. Flanking the south side of the central space are two bedrooms which have a shared central bathroom. On the north side of the living space is a single bedroom which opens onto a small side hallway that accesses a second bathroom. Instead of an additional bedroom on the north side, a kitchen occupies the remaining space. The characteristic central T-shaped portion of the second floor serves as a single multi-functional living space that gives the building an open plan. The interior finishes include hardwood floors and plaster walls. With the exception of the steel casement windows and Quarters O's lateral stair, Quarters O, P, Q, and R are identical to Quarters K through N, except for a slight change in building orientation.

Quarters S and T are primarily the same as the design of the original Panama Houses but they feature several changes. On the ground floor, there is no distinction between the concrete piers and the recessed bay walls. Instead, the ground floor walls have a flush surface which gives the façade a flat appearance. Additionally, the overhanging eaves do not have exposed rafters like the earlier renditions, instead covered with what appears to be either plywood or a type of composite board. The exterior lateral stair runs along the rear elevation rather than around a corner, and opens into the central living space on the second level at the rear of the building. The most significant change, however, appears in the design of the floor plan as mentioned previously.

The floor plan for the second level remains largely the same – a T-shaped central living space with rooms flanking the center portion of the 'T'. In Quarters S and T, however, each side of the 'T' is flanked by two bedrooms separated by a bathroom. Rather than have a kitchen at this level like the original Panama House design, the kitchen is moved to the ground floor. This signifies a shift in the spatial hierarchy of the buildings with primary living space now located on the ground floor; the second level in this design is meant to serve as sleeping space and secondary living space. The main entrance off the porch on the ground floor opens from the north into a reception room with a stair to the second level, similar to the earlier houses. The difference here is a doorway across from the main entry gives access to the first floor dining room while a door to the right opens into a powder room. A kitchen and laundry room extend west from the dining room along the south elevation of the building. This opens into the garage which is bordered on the opposite side by a servant's room and bath. At the center of the first floor is an additional room that is designated on the architectural plans for use as a "den," but its unfinished state indicates that it was likely used as storage.[4]

While the Panama Houses feature slight differences in terms of design, fenestration, materials and spatial layout, their common characteristics and identical shape and form distinguish them from other forms of housing at the Navy Yard as a single building type. The differences between the buildings signify the evolution of the Panama House design at the Charleston Navy Yard throughout the short period in which the buildings were constructed.

Contents of the Study

The results of this study are presented in the following chapters beginning with the literature review in Chapter Two. This chapter addresses vernacular studies, climatic design and tropical architecture in order to frame the discussion of the context of the Panama Houses and the preceding design from which they were derived. The methodological approach laid out in Chapter Three includes documentation, archival research, and the dataset and analysis. Chapter Four creates the context of the Panama Houses with a history of the Charleston Navy Yard from its establishment to base closure and realignment. Chapter Five provides a history of the Panama Canal Zone – its beginnings, construction

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[4] For additional details of the architectural description of the Panama Houses, please see Section 7, pages 20 through 24 of the National Register Nomination form for the District. Hampton Tucker et al, "Charleston Navy Yard Officers' Quarters Historic District," National Register of Historic Places Inventory/Nomination Form, Historic Preservation Consultants, Inc., Charleston, South Carolina, 19 January 2007, Section 7, 20-24.

and militarization – concluding with the end of U.S. rights in the zone when it is turned over to Panama. This chapter is meant to build context for the Panama Houses and the Canal Zone architecture from which it was derived. Chapter Six addresses U.S. military housing in the early-twentieth century before engaging Panama Canal Zone architecture as a definitive building type. This provides context and comparison for the Charleston Panama Houses with examples of housing from the Canal Zone in order to strengthen the connection between the designs. Canal Zone examples include both citizen and military housing from various locations and installations throughout the region, ranging from the first quarter of the twentieth century to the mid-twentieth century. The majority of these examples are single-family housing, although there are several exceptions that include multi-family quarters and apartments. Primary locations include Albrook Air Force Station, Fort Amador, and Fort Sherman.[5] Chapter Seven explores the factors that led to the importation of the Panama House design as a vernacular form at the Charleston Navy Yard focusing on climatic adaptation as a hypothesis. In pursuit of this question, the chapter addresses the use of data in the form of air flow simulations applied to 3D models of the Panama House designs to determine whether they effectively use passive cooling in the form of natural ventilation. Additional simulations are conducted on two control buildings – Quarters X and Quarters Y – which are also located in the Officer's Quarters

[5] Detailed information for each building and its corresponding installation in the Panama Canal Zone can be found in Appendix B. For more information on architecture in the Panama Canal Zone, see Edith Crouch, *Architecture of the Panama Canal Zone: Civic and Residential Structures & Townsites* (Atglen, PA: Schiffer Publishing, Ltd., 2014).

Historic District at the Navy Yard. The final theme of Chapter 7 presents the analysis of the simulations to assess the efficacy of the designs.

CHAPTER TWO:

LITERATURE REVIEW

There is not a wide variety of secondary literature on the Panama Houses aside from what is included in the National Register nomination form for the Charleston Navy Yard Officers' Quarters Historic District.[6] Several sources with information regarding the Charleston Panama Houses are available at various local repositories. The information gathered from those sources will be addressed in later chapters. This literature review assesses three topics regarding vernacular studies in architecture, climatic design, architecture in tropical regions, and briefly touches on United States military heritage of the twentieth century. Each of the sources that fall within these categories relates, either directly or indirectly, to the Panama House design and its history. Sources have been gathered that directly address the importance and evolution of vernacular studies, sustainable building for specific regions and climates, and comparisons of regional design which provide context for architecture rather than placelessness. Additionally, an analysis of studies that look at the various ways and methods in which buildings can be constructed in order to best adapt to regional climates provides information on how this historic practice of building is used

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[6] The National Register Nomination form provides an architectural description for the Panama Houses, as well as a reference to the plans of the Charleston Navy Yard located in the National Archives in Washington, D.C. For more information, see Section 7, pages 20 through 24 of the National Register Nomination form. Hampton Tucker et al., "Charleston Navy Yard Officers' Quarters Historic District," National Register of Historic Places Inventory/Nomination Form, Historic Preservation Consultants, Inc., Charleston, South Carolina, 19 January 2007.

throughout the world.

The sources that have been compiled include case studies, conference presentations, books, as well as various articles from academic journals and organizations. The vast majority of literature covered falls under the first two categories listed above, which have been written about extensively. These categories are not necessarily fixed, as there exists a great deal of overlap between them, particularly in the case of vernacular studies and climatic design. The sources addressed in this review are by no means an exhaustive compilation of sources available on the subjects that are covered. Rather, they represent the majority of sources and information available on their respective topics.

Vernacular Architecture

The Panama House is a building type first constructed at the Charleston Navy Yard in 1937 by the WPA. The design of the Panama House is modified from Army Quartermaster plans for housing in the Panama Canal Zone. Plans created by the Army Quartermaster were designed with climatic adaptive features to accommodate and work with the hot-humid climate of Panama as much as possible. Although not nearly to the same degree as that of Panama, the climate in Charleston is relatively hot and humid for an extensive portion of the year, often with mild winters.[7] For this reason, it seems fitting that a "Panama House" would be suitable for the climate of the Charleston region. As a building derived from an architectural type designed for a specific place, the Panama House, as situated in Charleston, can be analyzed as an imported and adapted vernacular building type.

The term vernacular as applied to architecture has existed since at least the nineteenth century. It evolved into vernacular studies, which falls under the larger umbrella of architectural history as a whole. A large amount has been written on vernacular architecture and vernacular studies over the last half-century. Much of the literature pertaining to vernacular studies addresses not only what vernacular architecture is, but how it has evolved over the last several decades, and its current role in the fields of historic preservation and architectural history.

In reviewing this topic, it is first necessary to provide a general definition of vernacular architecture. Scholars disagree on what vernacular architecture entails, meaning that their definitions for the subject differ, slightly or broadly. Some scholars even refuse to

[7] Charleston has an average monthly Dry Bulb Temperature (DBT) of 79.7 degrees Fahrenheit for the months of June through August with an average relative humidity of 77 percent for those same months. From December through February, the average DBT is 48 degrees F. with an average relative humidity of 70 percent. *Climate Consultant 6.0*, (Los Angeles, CA: UCLA Energy Design Tools Group, 2014), accessed 20 February, 2017, http://www.energy-design-tools.aud.ucla.edu/climate-consultant/. Climate Consultant was developed by the UCLA Energy Design Tools Group. Copyright © 2014 The Regents of the University of California. All Rights Reserved.

provide a clear definition altogether.[8] It used to be that vernacular architecture was defined as "traditional rural domestic and agricultural building."[9] Fortunately, over the last several decades, the field of vernacular studies has moved away from this narrow interpretation in order to provide a definition that encompasses many different building types from various places and time periods.

One of the most important individuals to the field of vernacular architecture is Dell Upton, who stated that he always tried to avoid defining the term, but when pressed, he preferred to define vernacular architecture "not as a category into which some buildings maybe fit and others not, but as an approach to architectural studies that complements more traditional architectural historical inquiries."[10] This definition can be applied to a broad spectrum of buildings, the majority of which would likely be described as traditional or regional, unlike high-style buildings that represent a particular movement in architecture. Another definition is provided by Kingston William Heath, who is also an important academic to the field of vernacular studies. Heath defines vernacular architecture as being

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[8] For various definitions on vernacular architecture or for what it means to be vernacular, see: Dell Upton, "Ordinary Buildings: A Bibliographical Essay on American Vernacular Architecture," *American Studies International* 19, no. 2 (1981).; Dennis Alan Mann, "Between Traditionalism and Modernism: Approaches to a Vernacular Architecture," *Journal of Architectural Education (1984-)* 39, no. 2 (1985).; Ahmadreza Foruzanmehr and Marcel Vellinga, "Vernacular Architecture: Questions of Comfort and Practicability," *Building Research & Information* 39, no. 3 (June 1, 2011).; Ken-ichi Kimura, "Vernacular Technologies Applied to Modern Architecture," *Renewable Energy*, Climate change Energy and the environment, 5, no. 5 (August 1, 1994).; Kingston Wm. Heath, "Defining the Nature of Vernacular," *Material Culture* 35, no. 2 (2003).; Kingston Wm. Heath, *Vernacular Architecture and Regional Design: Cultural Process and Environmental Response,* Amsterdam ; Boston ; London : Architectural Press, 2009.; Lindsay Asquith and Marcel Vellinga, *Vernacular Architecture in the 21st Century: Theory, Education and Practice*, Taylor & Francis, 2006.

[9] Upton, "Ordinary Buildings: A Bibliographical Essay on American Vernacular Architecture," 57.

[10] Dell Upton, "The Power of Things: Recent Studies in American Vernacular Architecture," *American Quarterly* 35, no. 3 (1983), 263.

composed of everyday forms that are indigenous and known to a region and people, often constructed using available materials in a functional manner by people responding to tradition or local adaptation.[11] Defining a seemingly simple term such as 'vernacular' presents more difficulties than anticipated, as is evident from the fact that experts in the field do not always entirely agree. In any case, the two primary definitions listed here, those by Upton and Heath, are fairly similar in their application, and will thus be applied as the broad definition for vernacular architecture as addressed in the remaining chapters.

Kingston Heath, former Director of the Graduate Program in Historic Preservation at the University of Oregon, has been a leading figure in vernacular studies since the 1980s. He has written extensively on the evolution of the field and the ever changing perception of what it means for a building to be vernacular. The definition of vernacular has been addressed by Heath in *Defining the Nature of Vernacular* (2003), in which he asserts that the term 'vernacular' has become so loosely applied over time by many people across various fields of study that its meaning has become muddled. Such connotation has become inconsistent, in part because Heath claims that traditional concerns of architectural history, such as who designed a building and what is its style, are being applied to vernacular architecture when they should not be. He asserts instead that the importance of the vernacular is that it is more informative of the social and cultural components of the region in which the building is situated, rather than in its stylistic influences. His primary goal in writing this article is

11 Heath, "Defining the Nature of Vernacular," 50.

to support his statement that “the term vernacular be applied more selectively to regionally and culturally distinctive works.”[12]

Heath also addresses the way in which vernacular forms emerge and change in response to regional patterns. He argues that regional settings are linked to cultural processes which shape vernacular forms. Vernacular forms respond to the ‘regional filter’ of an area through such factors as “economics, climate, cultural and religious values, demographic shifts, etc.”[13] Buildings are influenced by both internal and external components that eventually create a pattern that can be recognized as an established form in a particular region. Imported elements from outside can be brought in to blend with preexisting elements to undergo a process that the author calls “cultural weathering.” [14] Elements that enter a region but remain unaltered by that region continue to engage with the elements that originally shaped it.[15] Ultimately, Heath’s assertion is that if a form is imported into a region, but its original form is not altered to meet the standard of the new region, then it cannot be a vernacular form for the region into which it has been introduced. However, if its form does become altered in the new region, then it becomes a new vernacular form.

One of Heath’s most important publications is his book *Vernacular Architecture and Regional Design: Cultural Processes and Environmental Response* (2009). This work expands upon his preexisting works that apply to the field of vernacular studies. The

[12] Heath, “Defining the Nature of Vernacular,” 54.
[13] Heath, “Tradition and Change: A Method for Addressing Regional Distinctiveness,” 12.
[14] Ibid., 13.
[15] Heath, “Defining the Nature of Vernacular,” 51.

purpose of this book is to look at regionalism as it is shaped by social, cultural, and climatic properties which determine vernacular forms.[16] Heath presents this study in a way that architects and designers can gain an understanding of place in different regions without being outsiders looking in. Utilizing various case studies to drive his point, he is able to illustrate the ways in which vernacular forms can develop and change in regions, and how seemingly regular building forms can be adapted in order to improve their accommodation to the surrounding environs. One of the case studies Heath presents is the mobile home, which is a generally common building type across the United States and beyond. He uses this type to show how an architecturally blank form can be taken and adjusted to suit the climate in the region in which it is located, thus creating a vernacular form of a mobile home.[17] This concept can be applied to a wide array of architectural forms and building types, including the Panama house, as it is representative of a plan that was adapted from the Panama Canal Zone that was then placed in Charleston, SC.

Other authors focusing on vernacular studies have noted how the cultural and social meaning behind vernacular architecture, and its environmental performance, is often separated from how the building technology relates to the climate.[18] The authors of *Vernacular Architecture: Questions of Comfort and Practicability* (2011) addressed this in their case study of central Iran by first analyzing how the vernacular architecture of the

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[16] Heath, *Vernacular Architecture and Regional Design*, xiii.

[17] Ibid., 22-31.

[18] Foruzanmehr and Vellinga, "Vernacular Architecture: Questions of Comfort and Practicability," 275.

region has been shaped by cultural and climatic variables. The authors looked away from modern buildings that utilize electricity and mechanical cooling, and assessed the passive cooling methods of vernacular Iranian architecture in order to find out the measure of comfort provided by such methods.[19] Ken-ichi Kimura uses an alternative approach, instead focusing her journal article on how modern architecture can utilize vernacular technologies. Using traditional Japanese buildings as her case study, Kimura stresses the importance of 'bioclimatic design' through various methods to control solar shading, natural ventilation, and cooling. Such methods can be as simple as site orientation. Others include material choice, and roof form with large eaves to aid ventilation, cooling, and solar control.[20]

Ultimately, vernacular architecture frequently provides information for how people adapted their built environment in order to live in a region, both in the past and today. These regional differences and patterns are what make a place distinct - it is the "unique characteristics of the buildings which allow them to be identified with a place."[21] These differences also provide a unique opportunity to learn. Edward Chappell contends that vernacular architecture is an effective means for education which is true in terms of learning how a lieu of factors including social, cultural, and environmental, shaped and influenced vernacular architecture.[22]

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19 Foruzanmehr and Vellinga, "Vernacular Architecture: Questions of Comfort and Practicability," 277.

20 Kimura, "Vernacular Technologies Applied to Modern Architecture," 901-903.

21 Mann, "Between Traditionalism and Modernism," 10.

22 Edward A. Chappell, "Viewpoint: Vernacular Architecture and Public History," *Buildings & Landscapes: Journal of the Vernacular Architecture Forum* 14 (2007), 9.

Additionally, the vernacular is an effective means for moving forward today with modern building in the sense that an extensive amount of information can be pulled from vernacular architecture and applied to modern building. This belief is similar to that held by the authors of *Vernacular Architecture in the Twenty-First Century*, who state that scholars and conservationists tend to approach vernacular architecture as pre-modern and traditional which should be studied in its current state and protected in the modern era. This approach, however, limits the field of vernacular studies by hindering its development and obstructing its "potential relevance to the provision of sustainable architecture in the future."[23]

Climatic Design

The topic of climatic and environmental components incorporated into architectural design has an extensive overlap with both vernacular studies and tropical architecture. In terms of vernacular studies, climatic and environmental aspects of design are typically important factors when assessing regional adaptive forms. This overlap with the vernacular extends to tropical architecture, as it is representative of a region.

Torben Dahl claims that all architecture is affected by climate, which is due partly to the necessity of protecting the interior and the occupants from exterior environmental conditions, as well as the impact that a climate can have on a building as it wears over

23 Asquith and Vellinga, *Vernacular Architecture in the 21st* Century, 81.

time.[24] Despite the fact that it is necessary to protect building interiors from outside climatic extremes, it is equally important to work the climatic considerations into building design in a manner that is advantageous for the building, occupants, and surrounding landscape. Many of the books and articles that examine climatic design focus on natural ventilation and other passive design strategies, which are applied extensively in tropical and sub-tropical climates. Various publications that focus on building orientation in order to optimize solar performance stress the importance of site location and how the surrounding landscape might impact the building.[25] Regional conditions in conjunction with carefully thought out building location and orientation can aid in energy conservation and management.[26]

Passive methods are also advocated by Richard Hyde in *Climate Responsive Design* (2000), where he states that passive cooling systems are important in warm climates in order to alleviate discomfort.[27] Hyde refers to vernacular forms, which he calls "traditionally designed buildings" as a basis for the relationship between building and climate.[28] This is a recurring theme that can be found throughout the base of literature, but it should be remembered that vernacular forms of building are customarily not designed with solely the climate as the foundation of consideration. Rather, climate is one of several factors which

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24 Torben Dahl, *Climate and Architecture*, (Routledge, 2009), 13.

25 J. Morrissey et al., "Affordable Passive Solar Design in a Temperate Climate: An Experiment in Residential Building Orientation," *Renewable Energy* 36, no. 2 (February 2011), 568-569; Akubue Anselm, "Building with Nature (Ecological Principles in Building Design)," *Journal of Applied Sciences* 6, (2006), 959.

26 Anselm, "Building with Nature", 959.

27 Richard Hyde, *Climate Responsive Design: A Study of Buildings in Moderate and Hot Humid Climates,* (London; New York: E & FN Spon, 2000), 4.

28 Ibid., 7.

include cultural and social influences that shape vernacular forms.

Hyde attempts to define what climate is, stating that it is related to the atmospheric conditions of "temperature, wind, vegetation and light specific to a geographical location." To his credit, Hyde also provides an alternative definition that he attributes to Steven Szokolay, who relates climate to human comfort. Szokolay lists four factors that are important for thermal comfort: air temperature, humidity, air movement, and solar radiation.[29] These four factors can be influential in building design as they can be taken into account in the design process in order to provide adequate human comfort by alleviating unwanted conditions.

There is a consensus among the majority of authors in answering the question of what is the proper approach to a climate integrated design. Anselm Akubue provides a list of points that should be accounted for in a climatic design, which include understanding the variables of the climate, using it to your advantage, and selecting effective materials for the region in which you are building.[30] This approach is echoed by the authors of *The Climatic Dwelling* (1996), who state that a building's performance – whether it succeeds or fails – depends on its form, design, and orientation in relation to the outside environment.[31]

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[29] Hyde, *Climate Responsive Design: A Study of Buildings in Moderate and Hot Humid Climates,* 16-17.

[30] Anselm, "Building with Nature," 960.

[31] Eoin O. Cofaigh et al., *The Climatic Dwelling: An Introduction to Climate Responsive Residential Architecture,* Earthscan, (1996), 9.

Architecture in Tropical Regions

The subject of the design of tropical architecture can be sub-categorized under climatic design since it is representative of the adaptation of building design to meet the needs or limitations brought on by a particular climate. Tropical regions are typically classified as areas that fall close to the equator, and are situated between the Tropic of Cancer and the Tropic of Capricorn in the northern and southern hemispheres, respectively. Of course, there are some exceptions to these limitations, as some areas lying outside of these bounds feature tropical or subtropical climates, particularly along the coast of southern temperate regions. While Charleston does not quite have a tropical climate, it does feature some tropical aspects which include long hot-humid summers. Tropical regions can be subdivided further into hot-dry and hot-humid regions. The research undertaken for this portion of the study primarily focused on sources addressing hot-humid tropical climates, as it is this type of tropical climate that is representative of Panama and to which Charleston relates.

Much of the literature surrounding architectural design in tropical regions focuses on the theme of utilizing the natural environment to the advantage of building design in order to produce buildings and structures that are comfortable for the occupants while working in conjunction with the surrounding environment.[32] Several of these publications present their research and findings through case studies, some of which confine their focus

[32] Salmon, Cleveland. *Architectural Design for Tropical Regions.* (John Wiley & Sons, 1999), xv-xvii.

to a specific region while others employ multiple case studies across an array of regions and countries.[33] Both approaches have their advantages and disadvantages.

A variety of case studies that focus on one specific region, such as Southeast Asia, allow in-depth research and analysis to a greater extent than an assortment of case studies which address a range of regions. This is due in part to the fact that in looking at multiple regions, each individual case study is limited to addressing the tropical climate of its region of interest. This prevents any further development or analysis, which is contrary to the former approach in which each case study can address a different component or issue pertinent to the tropical climate of the one region around which all of the case studies are focused. In the approach of multiple case studies centered around a single region, authors focus on different aspects of the climatic approach to tropical building, such as heat profiles, the effectiveness of natural ventilation, performance of daylight, or the importance of urban planning in tropical regions.[34] This provides a much more scientific approach in terms of analyzing climatic data and how it affects buildings, which then allows the researcher to come to a conclusion of which design or designs best accommodate the environment.

Cleveland Salmon, in *Architectural Design for Tropical Regions* (1999), takes an alternate approach of providing regional profiles for various tropical regions, starting first

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[33] The publication by Joo Hwa Bay and Boon Lay Ong features case studies that focus on Southeast Asia, primarily Singapore and Taiwan. Alternatively, Cleveland Salmon's publication features a cross-regional approach with areas of focus falling across a wide array of regions which include the Caribbean, Australia and areas in the Pacific.
Joo Hwa Bay and Boon Lay Ong, *Tropical Sustainable Architecture*, Routledge, 2007.; Cleveland Salmon *Architectural Design for Tropical Regions*, John Wiley & Sons, 1999.

[34] Bay and Ong, *Tropical Sustainable Architecture*, 2007.

with the native architecture of each region, and then moving through the architecture of colonization before ending with climatic data for each region.[35] The second section of his book addresses climate and design, and the effects that climate has on building design. This is an important theme to all authors writing on design in tropical climates, as it can be found in nearly all publications on the subject. Design guidelines for tropical regions are provided by the authors in order to aid the reader, if they are looking to build in a tropical region, with the means to construct a building or structure in the most suitable manner. Such guidelines can include site selection and orientation, building plan, passive solar design and cooling, openings, as well as acknowledgment of natural disasters such as hurricanes that would necessitate additional considerations in constructing foundations and bracing.[36]

It is generally understood by authors that there is room for further research in tropical architecture in order to add to research already conducted; room exists for research to look into an issue that has yet to be analyzed or which looks at a component of tropical design from an alternative perspective. Baruch Givoni provides in *Climatic Aspects of Urban Design in Tropical Regions* (1992) various suggestions for further research in tropical regions. These suggestions include: design for effective ventilation in urban settings, as

35 Salmon, *Architectural Design for Tropical* Regions, 1999.

36 Salmon, *Architectural Design for Tropical Regions*, John 1999.; Baruch Givoni, "Climatic Aspects of Urban Design in Tropical Regions," *Atmospheric Environment, Part B, Urban Atmosphere* 26, no. 3 (September 1, 1992); Ardalan Aflaki et al., "A Review on Natural Ventilation Applications through Building Façade Components and Ventilation Openings in Tropical Climates," *Energy and Buildings* 101, (August 15, 2015).

well as the application of modern materials to improve indoor climate.[37] Further research needs to be conducted in ameliorating thermal discomfort in hot-humid climates, but scholars who advocate for this contradict themselves by stating that this is a problem that is "most difficult" to solve.[38]

U.S. Military Heritage

While there are numerous examples of sources outlining the history of military expansion during the twentieth century through the construction of new military bases, few publications actually address the preservation of U.S. military heritage.[39] In fact, there are so few publications which discuss the issue, that in researching and analyzing the literature encompassing various subjects for the purpose of this study, only one source was found directly regarding military heritage. This source - written by D. Colt Denfeld, and titled *Managing Our Military Heritage* – outlines how military events have impacted our history and why preserving the heritage associated with those events is important to understanding them and the traditions and values of our country. But this does not answer the question of what is military heritage? The author defines military heritage as encompassing buildings and structures, cultural items, objects, landscapes, records, and artifact collections.[40]

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[37] Givoni, "Climatic Aspects of Urban Design in Tropical Regions," 402-403.

[38] Ibid., 398.

[39] For additional information on the expansion of the navy during World War II, please see, "Building the Navy's Bases in World War II: History of the Bureau of Yards and Docks and the Civil Engineer Corps 1940-1946," (Washington: U.S. Government Printing Office, 1947).

[40] D. Colt Denfield, "Managing Our Military Heritage," *A Companion to Cultural Resource Management*, (Blackwell Publishing, 2011), 319.

The preservation of military heritage is extremely important, particularly in terms of its association with events that have greatly influenced the history of the United States and the world. This is due to the fact that much of the military heritage of the United States, aside from being associated with international conflict, is spread out in an international landscape in various countries. One important mechanism aiding military heritage is the increasing popularity of heritage tourism, which has led many people to visit important military sites such as Fort Moultrie – a Revolutionary War site in Charleston, SC which the author specifically mentions as an example.[41] Heritage tourism allows people to visit various sites of historic and cultural significance, making them increasingly aware of events that occurred in our history through a tangible means.[42] A large number of forts, bases, and other military sites are already open to the public, and heritage tourism allows these sites to inform all those who visit them.

Denfeld also provides information on "who saves our military heritage," referring to such groups as the Department of Defense (DoD), National Park Service and other federal agencies, state and local governments, as well as private owners. These various organization and groups preserve military sites with varying degrees of success, as there are limitations in the form of preservation awareness, priority and dedication, and availability

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41 Denfield, "Managing Our Military Heritage," 319-320.

42 The National Trust for Historic Preservation defines heritage tourism as "traveling to experience the places, artifacts and activities that authentically represent the stories and people of the past and present. It includes visitation to cultural, historic, and natural resources. Jamesha Gibson, "Preservation Glossary, Todays Word: Heritage Tourism," *National Trust for Historic Preservation*, 17 June 2015, accessed 1 March, 2017, https://savingplaces.org/stories/preservation-glossary-todays-word-heritage-tourism#.WLcjaFUrKUk

of funds.[43] This is due in part to the fact that preservation is not always the main priority of the government; or, in cases where it is important, the government often lacks the means or the funds necessary to successfully meet their preservation goals because the necessary funds are not often appropriated. The National Park Service is a good example as it has been a great proponent for historic preservation – which includes military heritage – but does not always have the funding necessary to adequately preserve all of the buildings, sites, and structures that fall under its control.

This is partially why the establishment of the Base Realignment and Closure Commission in 1988 is especially important. Denfeld states that military requirements since World War II meant that fewer bases were needed, which led to the establishment of the Commission whose purpose was to close and sell or transfer bases, thus consolidating resources. The author says that this process is overall beneficial, but that it also has negative aspects.[44] Although the preservation of historic properties is included in the process, "redevelopment" and "property managers… seek[ing] income-producing opportunities" may counteract the goals of historic preservation.[45] This can only be limited to a certain degree, however, as some prospective owners may promise to preserve sites but then go back on their word once a site or property has been transferred to them. Thankfully, such negative results are not the norm.

43 D. Colt Denfield, "Managing Our Military Heritage," 320-321.
44 Ibid., 325.
45 Ibid., 325.

The process of base closure and realignment is directly applicable to the Charleston Navy Yard, which was closed by the Navy in 1996. The portion of the base comprising the shipyard was sold to a private company, Detyens Shipyards Inc., for further use under the same purpose. The Officers' Quarters Historic District, however, was previously under the development of Noisette Company LLC, a property management and real estate company in Charleston that could have easily redeveloped the property for new construction. Instead, the district has been preserved and maintained by Noisette in conjunction with the City of North Charleston for the enjoyment of the public. Plans by the company call for the reuse of existing structures, incorporating the Officers' Quarters Historic District into the Master Plan for the Noisette Community. The Noisette Company promoted reuse and development through the use of tax credits, and helped manage the land transfer process and acquisition as master developer and property manager. With successful investment from businesses, the district has been revitalized. The Noisette Company no longer serves as property manager and does not own real estate within the Navy Yard anymore. Such actions by real estate companies are rare in the field of historic preservation, but this has proven beneficial for the preservation of the Officers' Quarters Historic District and the Panama Houses, as well as for military heritage.[46]

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[46] "Navy Yard Blog: About," *The Navy Yard at Noisette*, accessed 20 February 2017, https://navyyardsc.wordpress.com/about/

Conclusions

The literature base covered in this chapter varies in subject, concerning topics that fall under vernacular architecture, climatic design, architecture in tropical regions, and U.S. Military Heritage. Many sources and information exist regarding the first three categories, but, as previously stated there is substantial overlap. Climatic design is often a component of vernacular architecture, as the environmental and climatic influences of a region are often taken into account in the design and construction of vernacular building types.

The literature on vernacular studies follows a trend that tracks its evolution over the last several decades, and attempts to provide a definition which overwhelmingly seems to assert that vernacular buildings are ultimately shaped by regional influences and the social and cultural norms of their builders. In conjunction with regional, social, and cultural factors, the literature determined that climate has direct influence on vernacular forms. This was also evident in the literature on climatic design, with the authors often referring to vernacular forms as case studies for effective means of harnessing the climate through passive systems and building form.[47] The design of tropical architecture fell in close conjunction with climatic design, as many of the sources specifically written on tropical architecture primarily focus on how to effectively design buildings for the tropical climate. Ultimately, the literature that exists on these topics is substantial and provides a wide base of understanding moving forward.

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47 Kimura, "Vernacular Technologies Applied to Modern Architecture."; Foruzanmehr and Vellinga, "Vernacular Architecture: Questions of Comfort and Practicability."

The reverse is true, however, for literature on U.S. military heritage. Only one source could be found that specifically addresses the subject despite the fact that several sources exist outlining the history of U.S. military expansion in the twentieth century. It is recommended that more research on this subject be conducted in the field in the future in order to provide a greater understanding of military heritage and a point of comparison for the publication utilized in this chapter.

The four categories of literature that were analyzed provide the general foundation for an in-depth analysis and investigation of the Panama Houses at the Charleston Navy Yard. No secondary sources exist that investigate this building type to fully understand it's history, the factors that influenced its design, and the various functions and influences of the building features. The remaining chapters will build off the literature assessed in this chapter to conduct a detailed analysis of history and adaptation of the Charleston Navy Yard Panama Houses as an imported vernacular building type.

CHAPTER THREE:

METHODOLOGY

Description

Analysis of the Panama Houses at the Charleston Navy Yard as a vernacular building type relied on a diverse base of scholarly literature. This literature pertains to vernacular architecture studies, climatic design, and architecture for tropical regions. Further research for this thesis applied the National Register for Historic Places nomination form for the Charleston Navy Yard Officers' Quarters Historic District provided by the South Carolina Department of Archives and History (SCDAH), and primary sources such as impact statements, cultural resource and conditions assessments, historic photographs, as well as architectural drawings and construction documents. Analysis of these primary sources provided the information necessary to study the design and evolution of the Charleston Panama Houses in context with the vernacular form of the military housing within the Panama Canal Zone that they were derived from. Primary sources used in this analysis are located in the following local repositories: The South Carolina Room at the Charleston County Public Library (CCPL), the City Archives & History Room in North Charleston City Hall, the Historic Charleston Foundation archives, and the Charleston Naval Complex Redevelopment Authority archives. Additional sources regarding United States military housing in the Panama Canal Zone as an architectural type were gathered from the Library of Congress in Washington, DC and The National Archives at College Park, Maryland.

Documentation

Before assessing the effectiveness of the climatic adaptive features in the design of the Panama House, it was imperative to conduct site visits in order to understand the design and layout of the building type through an architectural investigation. The Panama Houses fall under the care of the City of North Charleston, specifically under the Naval Base Liaison within the Executive Department. With many of the Panama Houses not in use since the closure of the base, access was only allowed for two of the buildings: 'Quarters M' - one of the original four Panama Houses constructed along the riverfront, and 'Quarters T' – one of two Panama Houses comprising the second iteration of the design from 1941. Both buildings were photographically documented during the investigation using a Canon Rebel T2i. These photographs include elevations and images that show the context of the buildings within the Officers' Quarters Historic District. Additional photographs were taken of the various architectural elements and building features that represent climatic adaptive elements incorporated into the building design. Character defining features include: end-pivot casement windows, low-pitched hip roof with overhanging eaves, ventilation grates under the eaves, small louvered gable vents at center ridge, and a concrete floor slab. These photographs are used in conjunction with architectural drawings of the Panama Houses at the Charleston Navy Yard in order to compare and place them in context with designs for military housing within the Panama Canal Zone from which they were derived.

In addition to photographic documentation, field documentation was carried out using 3D laser scanning rather than the standard methods of field documentation. The decision to use digital documentation rather than standard methods was due in part to the high measure of accuracy provided by laser scanning, which is something that hand measuring does not accomplish to the same degree. Additionally, laser scanning requires much less time in the field to complete and record measurements. Due to vegetation and tree cover, the majority of the Panama Houses are too obscured to gather all of the required data to produce a full 3D rendering. Because its facades are the most easily visible in comparison to the other Panama Houses, it was decided that Quarters L would be documented. This was done using a Faro X330 scanner provided by Dr. Brent Fortenberry from the Warren Lasch Conservation Center. The Faro was first set up approximately 40 feet (12.192 meters) away from the building's southeast corner in order to gather data on the south and east facades for the first scan. This allows data from subsequent scans to more easily identify matching points in other scans. From this initial station, the laser scanner was slowly moved in a clockwise motion around the perimeter of the building to fully record its exterior features. The majority of these were taken from the same distance as the initial scan. After fully circumventing Quarters L with the scanner, additional scans were taken within close proximity of the building in order to record the details of smaller building features with greater accuracy; these details include the overhanging eaves with exposed rafters. In total, fifty-one scans were taken of Quarters L.

Once the scans were completed, they were downloaded from the scanner's sim card and uploaded to FARO SCENE, the corresponding software for the FARO X330 scanner. Once in SCENE, the scans were converted into a point cloud from which a 3D model of the building was produced. Using the model, orthographic images were taken and used to produce scaled drawings in AutoCAD. These drawings served as the base set for the creation of a 3D model of the Panama House using SketchUp. Orthographic and perspective images were taken of the SketchUp models in order to create a set of images used in Chapter Seven for the climatic analysis of the Panama House design. The completed set of images are compiled together in Appendix D.

Archival Research

In addition to field work and documentation, research was conducted on the Charleston Panama Houses and former Navy Yard. These sources came from several local archives and repositories. The archives at the Charleston Naval Complex Redevelopment Authority, located in Quarters H & I in the Officers' Quarters Historic District, were visited first in order to obtain copies of original and revision architectural drawings of the various CNY Panama Houses. These drawings were used to determine how the buildings have evolved and adapted throughout their period of significance. From these drawings, it was confirmed that there are two iterations of the design for the Panama Houses at the Charleston

Navy Yard. The first eight Panama Houses constructed in 1937 and 1938 fall under the first iteration, while the second iteration includes the final two buildings constructed in 1941. While the ground floors differ, both iterations maintain a similar second level with a relatively open floor plan that allows circulation and improved air flow on the interior. These original plans provide insight into the extent to which climate was a consideration for the designers of the buildings in terms of the building form and organization of space. More importantly, they provide a visual comparison in the analysis of the link with United States housing in the Panama Canal Zone.

Other local archives visited include the North Charleston City Archives and History Room overseen by Don Campagna. The North Charleston City Archives hold a wealth of information on the former Charleston Navy Yard, including a series of photographs documenting the construction of the first four Panama Houses at the Navy Yard as WPA projects. In addition to photographs, conditions assessments and inventories were located at the Historic Charleston Foundation archives. These sources, along with several of the Charleston Year Books located in the South Carolina Room at the Charleston County Public Library, provided information necessary to write the history of the Panama House and the Charleston Navy Yard.

The plans for the CNY Panama Houses constructed by the WPA in 1937 were adapted from original Army Quartermaster plans for housing in the Panama Canal Zone, hence their being locally known as Panama Houses. According to the National Register nomination form for the Officers' Quarters Historic District, these plans are located in the National Archives. However, no information to identify the particular source was given – only general information with a record group number which contains a vast amount of drawings. In order to locate these drawings, several days were spent at the Library of Congress in Washington, DC, and the Cartographic and Architectural Records room and Still Picture room at The National Archives at College Park, Maryland. During this visit, architectural drawings and photographs were collected for 35 different buildings at eleven different locations in the Canal Zone comprising both civilian and military housing. The information for each of these buildings was then entered into a Microsoft Excel spreadsheet, noting the type of source and date, the name of the building, its location in the Panama Canal Zone, and notes regarding similarities of the building to the Charleston Navy Yard Panama Houses. A separate form for each building recording this information featuring thumbnails of photographs and architectural drawings was then created in *Adobe InDesign*. These building forms can be found in Appendix B.

Comparative Analysis

The drawings and photographs for each building from the Panama Canal Zone show that the designs are similar in varying degrees to the Panama Houses at the CNY. Similarities depend on the size of the building, number of stories, architectural details, as well as date of construction. All of the Canal Zone buildings do have common features however, which include large, overhanging eaves - many with exposed rafters, as well as hipped roofs, ridge vents, and concrete foundations often with a partially or fully open ground floor to allow for cooling of the main floor above.

While it is not possible using known and available resources to ascertain the exact set of plans from which the CNY houses were derived from, the plans obtained from the National Archives show that many of the Canal Zone buildings have a nearly identical design in terms of plan and exterior appearance to those in Charleston. It is likely that the plans from one of these buildings was used as the base for the design of the CNY Panama Houses. These plans were analyzed and compared to the plans for the Panama Houses at the CNY to fully understand the extent to which they relate to one another – how much they conform and differ, and how they have been adapted over time – to provide context for the CNY Panama Houses as a vernacular building type and how they were imported and adapted from the vernacular housing in the setting of the Panama Canal Zone. The comparison and analysis of the designs are discussed fully in Chapter Six.

Data Collection and Analysis

One of the last measures of research for this study included data collection and analysis. This was conducted to explore the hypothesis of climatic design and adaptation as the primary factor for the importation of the Panama House design at the Charleston Navy Yard. In order to begin exploring this hypothesis, it was necessary to gain an understanding of the climates both in Charleston and the Panama Canal Zone. While other sources were utilized, *Climate Consultant* was the primary tool for the purpose of obtaining climatic data for analysis. *Climate Consultant* is a computer program that provides climate data for a specific location based off data made available by the Department of Energy. This data can then be visually displayed to show the relationship between climate and the built environment. Data from Charleston was pulled from this source while general climatic data for Panama was pulled from alternate sources due to the fact that *Climate Consultant* currently does not have data for Panama. The climatic data for both locations was used to determine whether the Panama House design uses passive cooling strategies more effectively in one location than the other.

In addition to climatic data, 3D models of two of the Panama Houses, Quarters M and T, were produced in order to simulate air flow through the buildings. The design of Quarters M follows the initial plans for the Panama Houses from 1937, while Quarters T is one of two Panama Houses that follow a slightly different design from 1941. The purpose of running the simulation was to determine how effective, if at all, the designs of the Panama Houses are in using passive cooling, and if so, which iteration of the building type is more successful in this effort. In order to more accurately determine the effectiveness of the Panama House design, two other quarters at the Navy Yard from approximately the same time period, Quarters X and Y, were modeled and simulated. This was done so that Quarters X and Y may serve as controls for the Panama Houses in order to definitively conclude whether the Panama House design is indeed better suited to the climate than other officers' quarters at the Navy Yard.

Three models were created for each building in order to observe and understand how air moves through the buildings while conducting the simulations. These include individual models of the first floor, second floor, and building as a whole that were produced for the Panama Houses and Control buildings. These were used because it is impossible to gain a full understanding of how air moves through each floor if the simulation is simply run on a model of an entire building, as the roof obstructs visual observation of the full interior space for each floor, preventing observation of air circulation through the building.

The models for each building were produced in SketchUp using images from the laser scan, and drawings created using measurements from the Panama House drawings located in the Charleston Naval Complex Redevelopment Authority Archives. From there, they were exported from SketchUp as 3ds files in order to import them into Autodesk Flow Design to run the simulation. This computer software is a wind simulator that produces visual representations of air flow around and through a building. By carrying out this simulation for Quarters X and Y in addition to both iterations of the Panama House design, it was possible to compare and analyze the different designs and their ability to utilize natural ventilation as a passive cooling technique.

Climatic data gathered from *Climate Consultant*, in conjunction with the 3D rendering and air simulations conducted on the Panama Houses and control buildings, provides the necessary data to determine the efficacy of the Panama House design in the Charleston climate compared to the climate of Panama. The results of this simulation and data collection are presented in Chapter Seven.

CHAPTER FOUR:

HISTORY OF THE CHARLESTON NAVY YARD

Overview

The Charleston Navy Yard provided service to the United States Navy for nearly a century from its establishment in 1901 to its closure and realignment in 1996. When it opened, the Navy Yard provided economic relief for an area that had never quite recovered from the American Civil War. Thousands were employed at the yard throughout its active years, many coming from around the nation to work at Charleston's Navy Yard.

Located several miles up the Charleston Peninsula on the banks of the Cooper River, the Navy Yard provided a multitude of services throughout its history. These services included the building of new ships, providing maritime vessel repair and refitting, and the decommissioning of wartime vessels. Known as the Charleston Navy Yard when it was first established, the yard was redesignated in late 1945 as the Charleston Naval Shipyard, one of nine commands incorporated into the United States Naval Base, Charleston. The yard saw increases in employment and production during times of war, and decline during periods of peace due to a fall in demand for military production. There were several instances, primarily between the First and Second World Wars, in which the yard was slated for closure, but each time it was saved through the efforts and dedication of city and state leaders who realized the importance of the yard and fought for its existence. Due to these efforts, the yard continued to serve as a functioning naval installation until its closure in 1996.

Today, the yard has three historic districts that have been listed on the National Register of Historic Places, with portions of the base having been sold or leased to businesses. This has led to the ongoing revitalization and preservation of the former Navy Yard and its facilities, which are again becoming an important part of the North Charleston economy.

Before the Yard - Chicora Park

Before the establishment of the Navy Yard, the area along the west bank of the Cooper River included portions of private lands such as Marshlands Plantation and land owned by the City of Charleston which was being developed as a park. The land for the park was bounded to the north by Noisette Creek, to the east by the Cooper River, to the west by reclaimed land, and to the south by private land. The City purchased the land for the development of the park, which held the former Turnbull Plantation house, and had the land commissioned under the name of Chicora Park in 1895. During the same year, the Board of Park Commissioners acquired the services of "Messrs. Olmsted, Olmsted and Elliot, of Brookline, Massachusetts" to design the grounds for the park.[48]

The Olmsted brothers' firm visited the site for Chicora Park in 1896 to become

48 *Yearbook, City of Charleston, S.C., 1895,* (Charleston: News and Courier Book Presses, 1896), 194.

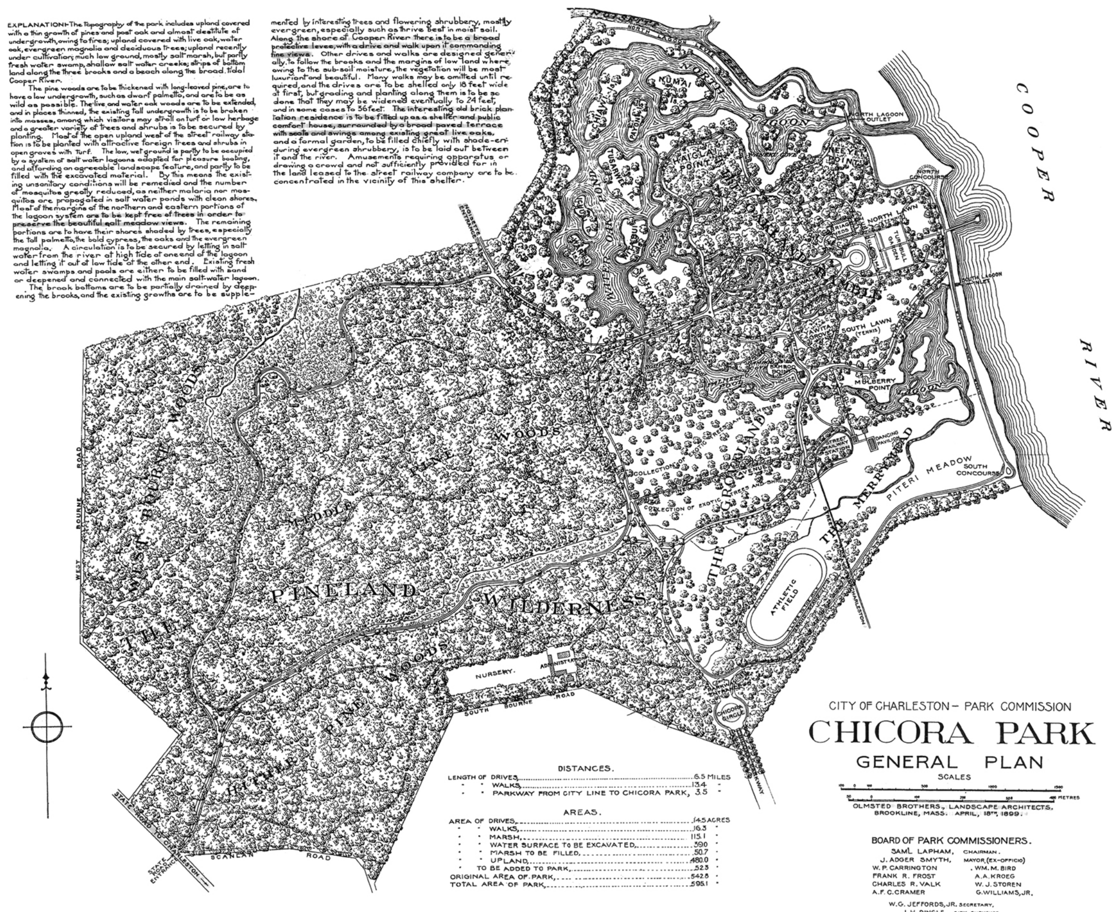

Figure 7: *Olmsted Brothers, "Chicora Park General Plan". Image courtesy of City of North Charleston Archives.*

acquainted with the grounds so that they could draw up formalized landscape plans.[49] The general plan for Chicora Park as designed by the Olmsted brothers had a formal area along the banks of the Cooper River and Noisette Creek that included lagoons, gardens, and winding paths that the firm called "The Oakland Ramble"; this is the area that includes the Officers' Quarters Historic District today. To the west of this area is land that was reclaimed with pine trees, likely for the purpose of harvesting for lumber. While winding paths were

[49] *Yearbook, City of Charleston, S.C., 1896,* (Charleston: News and Courier Book Presses, 1897), 250.

still included in the plans for this area, it was to be less formal than the "Oakland Ramble," merely described on the park plans as "The Pineland Wilderness."[50]

Development of the park progressed with construction of a pier and the extension of an electric trolley railway line to the park in 1897. Landscaping according to the plans of the Olmsted brothers continued, and a keeper's cottage was constructed in 1898 as the permanent residence of the of the park manager. Buildings were also planned by the railway company for the station at the park where individuals disembarked. By the first of the year in 1901, the contract with the Olmsted brothers to design and oversee construction of the park expired. In advance of the expiration date, they sent a detailed plan and layout of Chicora Park in full which allowed further planning and development for areas of the park that were not already underway. This plan was not carried out by the Park Commission in full, however, due to the fact that there was already speculation earlier in 1900 that Chicora Park might be sold to the federal government for use as a Naval Station. In light of this, the Park Commissioners kept expenditures to a minimum for the rest of the year in order to avoid unnecessary spending.[51]

Establishment and Early Years

On August 12, 1901, the U.S. Government purchased the property of Chicora Park from the City of Charleston for use as a Naval Station. Leaders in the City of Charleston

[50] Olmsted Brothers, "Chicora Park: General Plan" (Boston: Heliotype Printing Co., 1899).
[51] *Yearbook, City of Charleston, S.C., 1900*, (Charleston: News and Courier Book Presses, 1901), 174-175.

Figure 8: *The Great Dry Dock, Charleston Navy Yard. Image courtesy of the Library of Congress.*

and the state of South Carolina spent years prior to 1901 lobbying for a Naval Station for years in hopes that such an installation would help rejuvenate the local economy and bring jobs to the stagnant city.[52] The fact that the city was willing to sell Chicora Park for this purpose lends credence to just how badly they wanted the Navy to choose Charleston as the new site for a Navy Yard. However, not everyone in the city was overjoyed with the news. The Park Commissioners wrote in their yearly report published in the 1901 City Year Book that the sale to the United States government of the land took from the park "all part on

52 Hampton Tucker et al., "Charleston Navy Yard Officers' Quarters Historic District," National Register of Historic Places Inventory/Nomination Form, Historic Preservation Consultants, Inc., Charleston, South Carolina, 19 January 2007, Section 7, 6.

which improvements had been made... and the area that possessed most of the great natural beauties which rendered Chicora Park so attractive; and which…would have made Chicora Park one of the finest public parks in the United States." Despite this, all lamentations were ignored and the sale was eagerly approved by the City.

The federal government purchased approximately 1,189 acres along the Cooper River for the Naval Station. This included not only Chicora Park, but property from Marshlands Plantation and a large piece of land to the south comprised of marshes. This meant that there were actually three separate transactions in the sale of property to the federal government for the Navy Yard. 171 acres of Chicora Park were purchased by the Navy for $34,307 along with 258 acres of Marshlands Plantation for $50,000. The final piece of property was the sale of the 760 acres of Marshland to the Navy for the sum of one dollar.[53] The Navy wasted little time with construction on the Navy Yard beginning in 1902. It was not until 1909 that the first dry-dock was completed; the first dry-docking took place on April 7th of that year.[54] With completion of the dry-dock, the Yard could begin producing ships for the Navy.

During its first years of operation, the Navy Yard provided approximately 400 new jobs for the city, thus bringing a small degree of economic relief. It would not be until the outbreak of World War I, however, that the Navy Yard became an important component in

[53] Jim McNeil, *Charleston's Navy Yard: A Picture History*, (Charleston, SC: Coker Craft Press for the Naval Civilian Administrators Association, 1985), 40.
[54] Ibid., 42.

the local economy.[55]

World War I

The First World War did not drastically impact the Navy Yard until April of 1917 when the United States entered the conflict. With America's entrance into the Great War, activity at the Navy Yard expanded as new warships were needed to fight in the conflict. Wartime activity meant a drastic increase in civilian employment at the Yard from approximately 1,700 to over 5,000. A temporary training camp was established during the war in order to train more than 5,000 sailors before war's end.[56] The Navy Yard worked during the war to produce new ships and provide alterations and repairs to older vessels and those in need of repair. Wartime also saw an expansion in building projects, including the construction of several industrial buildings and a naval hospital. Through the increase in civilian employees and military personnel, along with the expansion of facilities and infrastructure, the Navy Yard had become a vital component in the local economy.[57]

The economic relief that the war brought was short-lived as America's involvement in the war lasted less than two years by the time it ended in November of 1918. The end of the war meant a decrease in employment and activity at the Navy Yard as there was no

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55 Fritz Hamer, *Charleston Reborn: A Southern City, its Navy Yard and World War II*, (Charleston: History Press, 2005), 16.

56 Jack C. Sprott, "Charleston Naval Complex," *Economic Development Journal,* 1, no. 2 (Spring 2002), 23.

57 "Naval Base History," *City of North Charleston*, 2016, accessed 3 September 2016, http://www.north-charleston.org/Visitors/Attractions/Greater-Charleston-Naval-Base-Memorial/Naval-Base-History.aspx.

longer a high demand for new warships. The following years promised an uncertain future for the Charleston Navy Yard as a decline in employment and production soon took hold.

Inter-war Period

After the end of World War I, the nation entered a period of peace and post-war prosperity as employment and production at the Navy Yard returned to pre-war levels.[58] Satellite functions of the Navy Yard implemented during the war were deemed to be no longer necessary, which led to the closure of the Naval Training Camp and Naval Clothing Factory.[59] Falling employment and workload led to the Navy's decision in 1922 to close the Charleston Navy Yard. However, Charleston leaders fought to keep the yard open and persuaded the Department of the Navy to do so, thus saving Charleston from losing an important part of its economy.[60]

Despite being saved from closure, employment at the Yard stood at approximately five hundred, a relatively low number, throughout the decade. By 1931, the Navy again recommended that the Navy Yard be closed, but once more, city and state leaders protested and advocated for the yard, leading to the cancellation of the closure.[61] Two years later in 1933 during the midst of the depression, the yard was again threatened with closure.

58 "Naval Base History," accessed 3 September 2016.
59 McNeil, *Charleston's Navy Yard*, 77.
60 Ibid., 77-78.
61 Fritz Hamer, *Charleston Reborn*, 21.

However, President Franklin D. Roosevelt was working to reinvigorate not only the national economy but local economies as well, and Charleston was suffering. The Navy decided to use New Deal programs to fund new construction at the Navy Yard in order to revitalize the base and bring new employment. During the 1930s, the Charleston Navy Yard used WPA funds to employ hundreds of workers in a new period of construction. It was during this time in 1937 that the first four Panama Houses along the Cooper River were constructed as WPA projects.[62]

Aiding in the growth and strengthening of the base was the designation in 1933 of Charleston as a new construction yard which expanded the work load to allow an increase in production and employment.[63] In 1939, civilian employment at the Navy Yard reached its greatest number since the First World War ended over twenty years earlier.[64] Employment continued to grow, exacerbated by the outbreak of World War II.

World War II

With the bombing of Pearl Harbor on December 7, 1941, the United States entered World War II. By this time, the Navy Yard had become the largest employer that the state had ever known with approximately 25,000 workers.[65] This number would reach its peak

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62 Fritz Hamer, *Charleston Reborn*, 21-22.
63 Jim McNeil, *Charleston's Navy Yard*, 78.
64 Ibid., 79.
65 Jack C. Sprott, "Charleston Naval Complex," 23-24.

***Figure 9**: Aerial photograph of the Charleston Navy Yard, 1941.* Several of the Panama Houses can be seen in the mid-upper portion of the photo on the left edge of the wooded area. *Image courtesy of the U.S. Navy, Naval History and Heritage Command.*

in 1943 with a total of 25,943 people working at the yard.[66] With increasing employment, the yard also saw a large number of its workers leave their positions in order to join the military. In total, over 4,000 workers joined the military throughout the war, many of them being replaced by women, thousands of whom were employed at the Navy Yard during the peak of the war.[67]

The start of the war led to the production of ships at a rapid pace with the yard

66 Jim McNeil, *Charleston's Navy Yard*, 99.

67 Ibid., 100.

launching a new vessel almost every week. From August 1939 to the end of the war with the surrender of Japan, the Navy Yard built a total of 216 vessels ranging from warships to landing craft for the European invasion.[68] In addition to new construction, the shipyard worked on refitting and repairing hundreds of vessels throughout the war for both American and foreign warships.[69] The repair of naval vessels quickly became the top priority for the yard as refitting and returning them to the sea for combat was deemed more important than the construction of new vessels.

Despite the construction efforts and increases in Navy Yard production and employment during the 1930s, the wartime increase in work-load led to the need for additional expansion. This came in the form of new housing for workers, as well as the construction of five additional production shops and a second dry-dock to meet the demands of wartime production.[70] The World War II expansion period also saw the construction of the second iteration of the Panama House in the Officer Quarters' Historic District. Quarters S and T were constructed in 1941, the last Panama Houses to be built at the Navy Yard.

During the war, the role of the Charleston Navy Yard was elevated to higher stature when it was designated as the headquarters for the Sixth Naval District, one of twelve naval districts in the nation.[71] With its growing role for the Navy and the war effort, the Charleston

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68 Jim McNeil, *Charleston's Navy Yard,* 101.
69 Ibid., 99.
70 Ibid., 100.
71 Fritz Hamer, *Charleston Reborn*, 38.

Navy Yard continued to produce and repair ships throughout the war. However, as the war drew to a close, employment began to decline. By August of 1945 with the surrender of Japan, employment had fallen to 20,000 from a wartime peak of nearly 26,000. The end of the war meant that the high levels of warship construction and repair were no longer necessary. This led to the Navy cancelling ship construction contracts and ordering more cutbacks in employment. By September of 1946, the workforce at the Navy Yard stood at less than 10,000.[72]

Post-War

The end of the war did not mean the end of the Navy Yard. On November 30, 1945, the shipyard was designated a U.S. Navy Base and began integrating the Naval functions that existed in and around Charleston at that time. The components of the newly designated Navy Base included the Charleston Naval Shipyard, Naval Air Station, a Naval hospital, a radio station, receiving and training stations, a marine barracks, a small base on the Ashley River and an ammunition depot on the Cooper River that was located upriver from the yard.[73]

The beginning of the post-war period meant not only a drastic decrease in enlisted men as they returned to civilian life, but a surplus of naval vessels that needed to be

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72 Ibid., 134.

73 Sprott, "Charleston Naval Complex," 24.

decommissioned. The workload at the Charleston Navy Yard shifted from new vessel construction to preparing ships for retirement and the disposing of surplus materials that were no longer needed. Surplus ships were lined up in rivers and moored in groups due to the fact that more ships came in than could be decommissioned at one time. The yard eventually decommissioned approximately four hundred vessels which became a part of the Atlantic Reserve Fleet. In addition to decommission efforts, the yard also prepared American ships used during the war for transfer to other countries to aid in building their navies.[74]

In 1948, the yard's role and function again shifted as it was designated a submarine overhaul yard by the Bureau of Ships, making the repair of submarines a primary component of the work for the Navy Yard in addition to the repair and overhaul of ships. This supporting role meant that the yard converted and installed the latest technology into warships in order to keep them up to date and modernized.[75] Not long after the shift to submarine overhaul, the Navy Yard was threatened with closure in 1949 as the federal government sought to cut back work at naval shipyards. Once again, local and state leaders joined shipyard employees to fight to save the yard. State Senators managed to convince the Secretary of the Navy and the Chief of Naval Operations to keep the yard open, compromising with a reduction in Navy Yard employment that brought the level of workers down to less than

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[74] McNeil, *Charleston's Navy Yard*, 146.
[75] Ibid., 145.

five thousand.[76] Despite reaching a post-war low in employment, the base was saved once again.

The further decline in employment was short-lived as the outbreak of the Korean War in 1950 lead to an increase in employment. Yard employment reached a high of more than nine thousand during the conflict as new vessels were required. At the end of the war, the base returned to submarine and ship overhaul and repair.[77]

In 1956, the Bureau of Ships decided to designate Charleston as a nuclear shipyard. This expanded the yard's role to work on nuclear-powered submarines.[78] Several years later in 1962, Work was begun on Dry Dock 5 which was the biggest construction project that the installation had seen since World War II. This was built in order to accommodate overhaul and maintenance of Polaris class submarines and nuclear warships.[79] The expansion of the Navy Yard during the 1950s and 1960s ensured the Charleston Navy Yard's role for the Navy, keeping the base active and safe from closure until the 1990s.

In October 1979, naval districts were dis-established. Despite this, the Charleston Navy Base was the third largest naval home port in the United States in 1983, employing over 36,000 people. The Navy Yard continued to be a vital part of the economy and the

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[76] McNeil, *Charleston's Navy Yard*, 147.
[77] Ibid., 148.
[78] Ibid., 149.
[79] Ibid., 167.

largest state employer in South Carolina until the 1990s with the end of the Cold War.[80]

Base Closure and Realignment

The end of the Cold War meant the decline in the threat of nuclear attack against the United States. This led to a cut in the defense budget, threatening the Charleston Navy Base. Between 1991 and 1992, the work force at the base dropped to six thousand as workers were laid off. In 1993, it was announced that the Navy base would be closed on April 1, 1996.[81] The closure dealt a huge blow to Charleston's economy as more than 20,000 jobs were lost and the millions of dollars that once flowed into the economy from the base ceased. In 1993, the South Carolina governor assembled a committee in order to develop a reuse plan for the Charleston Naval complex in order to prevent the installation from falling into complete disuse and disrepair upon closure.[82]

In 1994, the committee approved a plan to focus on areas of employment including a shipyard, industrial park, office district, and a community park and support district. Legislation was passed to create the Charleston Naval Complex Redevelopment Authority (RDA) charged with overseeing the reuse and redevelopment of the former facilities and property of the Navy Yard.[83] The RDA set to creating a waterfront park for the City of

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80 "Naval Base History," *City of North Charleston*, 2016, accessed 3 September 2016, http://www.north-charleston.org/Visitors/Attractions/Greater-Charleston-Naval-Base-Memorial/Naval-Base-History.aspx.

81 Sprott, "Charleston Naval Complex," 24.

82 Ibid., 24.

83 Sprott, "Charleston Naval Complex," 25.

North Charleston which became the Noisette project. Due to the efforts of the state and local government and the actions of the RDA, millions of dollars have gone into improving the Navy Yard. Today, dozens of businesses and agencies operate on the base and thousands of jobs have been created.[84]

Since the closure of the yard, three historic districts have been established: the Charleston Navy Yard Officers' Quarters Historic District, the Charleston Navy Yard Historic District, and the Charleston Naval Hospital Historic District. The addition of these historic districts to the National Register has aided in the preservation of the former naval installation, allowing buildings and facilities to be preserved and reused as they continue to serve as a visual reminder of the history and importance of the Charleston Navy Yard.

84 Sprott, "Charleston Naval Complex," 28.

CHAPTER FIVE:

HISTORY OF THE PANAMA CANAL

Overview

The Panama Canal is one of the greatest modern engineering marvels despite being completed over a century ago. The United States, however, was not the first nation to attempt to build a canal to connect the Atlantic and Pacific Oceans. Since the discovery of the Americas, explorers have long searched for fabled waterways through the isthmus in central America. Some, including Lewis and Clark, sought to find a similar waterway – the Northwest Passage – through the United States. With the 'discovery' of the Pacific Ocean by Vasco Nunez de Balboa in 1513, ideas of a canal through what is now Panama were inspired by the short distance between the two oceans across the Panama isthmus. In 1534, King Charles I of Spain ordered a survey be conducted in order to find a canal route, but the survey determined that such a feat was impossible.[85] Charles I continued to consider a canal for a time, but eventually abandoned his search for a route, stating that "if God wanted the oceans to meet He would have built the Canal himself."[86]

During the nineteenth century, Spain lost its hold on South and Central America

[85] Susan I. Enscore et al., "Guarding the Gates: The Story of Fort Clayton – Its Setting, Its Architecture, and Its Role in the History of the Panama Canal," (Champaign, IL: U.S. Army Corps of Engineers, 2000), 1-1.

[86] Suzanne P. Johnson, "An American Legacy in Panama: A Brief History of the Department of Defense Installations and Properties; The Former Panama Canal Zone, Republic of Panama," (Fort Clayton, Panama: Directorate of Engineering and Housing, 1994), 4.

Figure 10: *Map of the isthmus of Panama showing the route of the Panama Railroad. Image courtesy of the Library of Congress.*

as the political climate began to shift. Revolutionary movements ended Spanish rule and established newly independent countries. Panama declared its independence in 1821, but was in need of military support; as a result, they allied with Gran Colombia. A decade later, when Gran Colombia dissolved into three separate countries, Panama was annexed as a province of the Republic of Colombia.[87]

In 1848, the discovery of gold in California led to the U.S. development of a trans-isthmian railroad through Panama. Development of the railroad allowed people traveling to California by ship from the east coast of the United States to arrive there much faster than if they were to travel across the country. The Panama Railway Company was America's first foray into Panama, but it demonstrated the value and importance of a fast route across the isthmus. It was not long before the U.S. became interested in a canal through Central America, but the French beat them onto the scene.[88]

The French Canal

In 1869, the Suez Canal, connecting the Mediterranean and Red Seas, was completed by the French. Work on the Suez was so successful that the French ambitiously thought they could complete a second canal, this time through Panama. Quick to secure this position, the French purchased rights to construct a canal from Colombia in 1879. The

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87 Enscore, et al, "Guarding the Gates: The Story of Fort Clayton – Its Setting, Its Architecture, and Its Role in the History of the Panama Canal," 1-1.

88 David McCullough, *The Path Between the Seas: The Creation of the Panama Canal, 1870-1914*, (New York: Simon and Schuster, 1977), 40-44.

French arrived in the region in 1881 with the canal effort under the command of Ferdinand de Lesseps, the same man who led the construction of the Suez Canal. Under the newly formed La Compagnie Universelle du Canal Interoceanique, the French company created to complete canal construction, Lesseps got to work. He was determined to build a sea-level canal despite the rugged terrain of Panama.

After conducting a survey, a canal route was chosen along the Rio Chagres and Rio Grande.[89] Planning for a sea-level canal meant that there would be no locks, but the construction would require a greater amount of excavation than a lock canal. Lesseps planned to complete the project in just twelve years at an estimated cost of $132 million. However, by 1888, the project had consumed double that amount while only covering a third of the required distance. Unforeseen complications also arose due primarily to disease in the tropical climate that lead to the deaths of over 16,000 workers. As a result of these setbacks, Lesseps decided to construct a lock canal in order to reduce the amount of required digging so that the company could save time and money. It proved too late, however, to save the canal. High expenses, financial corruption, bad management and high death rate from disease combined to bring the project to an end in 1889.[90]

No work was done on the canal for over a decade after the abandonment of the French effort. It was not until 1903 that the French sold the rights to build a canal to the

89 Suzanne P. Johnson, "An American Legacy in Panama: A Brief History of the Department of Defense Installations and Properties; The Former Panama Canal Zone, Republic of Panama," 7.

90 Jon T. Hoffman et al., *The Panama Canal: An Army's Enterprise*, (Washington, D.C.: Center of Military History, United States Army, 2009), 6.

Figure 11: *Abandoned French equipment, 1908.* This equipment was used in the French Canal effort, then abandoned and overtaken by the Panamanian jungle. *Image courtesy of the Library of Congress.*

United States.[91] The agreement between the Americans and the French included the sale of all "machinery and equipment, administrative records and files, and over 2,100 French residential and civic buildings."[92] Most of the equipment proved to be useless as vegetation reclaimed many of the structures and equipment that the French abandoned in the jungle. However, the work that the French already completed, along with the records and files, proved to be indispensable and served as the ground work for the U.S. construction of the canal. The decision by the French to switch to a lock canal provided foresight to prevent the Americans from making the same mistake of attempting to construct a sea level canal;

91 Edith Crouch, *Architecture of the Panama Canal Zone: Civic and Residential Structures and Townsites*, (Atglen, PA: Schiffer Publishing Ltd, 2014), 20.

92 Ibid., 9.

the topographical surveys and twenty miles of canal already excavated were also crucial to American engineers.

U.S. Interest

While American interest in an isthmian canal increased with the Panamanian Railroad, the Spanish American War pushed political and militaristic concerns to the forefront as the major driving force for canal construction. It was determined that a canal was important for national defense as technology developed and foreign navies were expanding. During the Spanish American War, the USS Oregon had to sail around Cape Horn to get to the Caribbean from San Francisco. Fortunately, it arrived in time to take part in the Battle of Santiago to defeat the Spanish Fleet. This highly publicized event reinforced the need for a canal.[93]

To construct a canal, the U.S. needed first to remove the obstacle of the Clayton-Bulwer Treaty of 1850. The treaty reflected British-U.S. contentions in the Caribbean and forbade the U.S. from independently building a canal or exercising control over one.[94] By the end of the nineteenth century, however, the treaty was obsolete as the U.S. was developing into a world power, and Britain was beginning to maintain a smaller presence in the Caribbean. To remove the treaty, John Hay, Secretary of State, met with

93 Jon T. Hoffman et al., *The Panama Canal: An Army's Enterprise*, 1.

94 Paul B. Ryan, *The Panama Canal Controversy: U.S. Diplomacy and Defense Interests*, (Stanford: Hoover Institution Press, 1977), 7-8.

British ambassador to Washington, Lord Pauncefote, to engage in diplomatic discussion in December 1898. By February of 1900, the two parties agreed that the United States would have the rights to construct and operate a canal in Central America. Following the guidelines of the Constantinople Convention of 1888 which regulated use of the Suez Canal, both Hay and Pauncefote agreed that the isthmian canal was to be unfortified, open to vessels of all nations at all times, and open to other nations who could be parties to the agreement.[95]

Hay believed that it was important not to fortify the canal, stating that "only an imbecile government would think of fortifying." The rest of the American government, however, was under the impression that fortifying was essential. Amendments were made to Hay's treaty to allow for the fortification and defense of the canal. Ultimately, the Constantinople regulations were not to apply. Roosevelt believed that defense of the canal must be by fortification rather than by Naval blockade in order to allow the Navy to have offensive capabilities rather than be tied down to one location. The changes were made and approved by the senate; the treaty was signed on November 18, 1901.[96]

In order to determine the best route for the canal, the American government created a commission to survey the region. Nicaragua and Panama were the two areas in Central America that the government was considering. The commission recommended a canal

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95 John Major, *Prize Possession: The United states and the Panama Canal, 1903-1979*, (Cambridge: Cambridge University Press, 1993), 25-26.

96 Ibid., 26, 155.

through Nicaragua, but this was in part due to the fact that at the time, the French canal company was asking $109 million for its holding in Panama, more than double what it was valued by the United States. Despite their recommendation, the commission actually favored Panama since it would be a third the length of a canal in Nicaragua, require fewer locks, and at would be cheaper to navigate and operate. Additionally, Panama had harbors on both coasts the canal could connect. Eventually, it was decided that Panama would be the location for the canal, with the French agreeing to sell their company and assets to the Panama Railroad Company for $40 million. In June 1902, Congress passed the Spooner Act to authorize work on a Panamanian canal.[97]

Independence and Subjugation

Despite purchasing rights from the French and approving Panama as the region for constructing the canal, the United States still needed permission from Colombia since Panama was a province of the South American nation. The Colombian government rejected a treaty offered by the U.S., demanding more money for rights to the canal and a higher annual fee than the American government was willing to offer. The U.S. knew, however, that Panama was seeking independence from Colombia. This provided an opportunity for the U.S. to circumvent obtaining permission from Colombia. On November 3, 1903, Panamanians revolted against Colombia and proclaimed their independence. The United

[97] Jon T. Hoffman et al., *The Panama Canal: An Army's Enterprise*, 8.

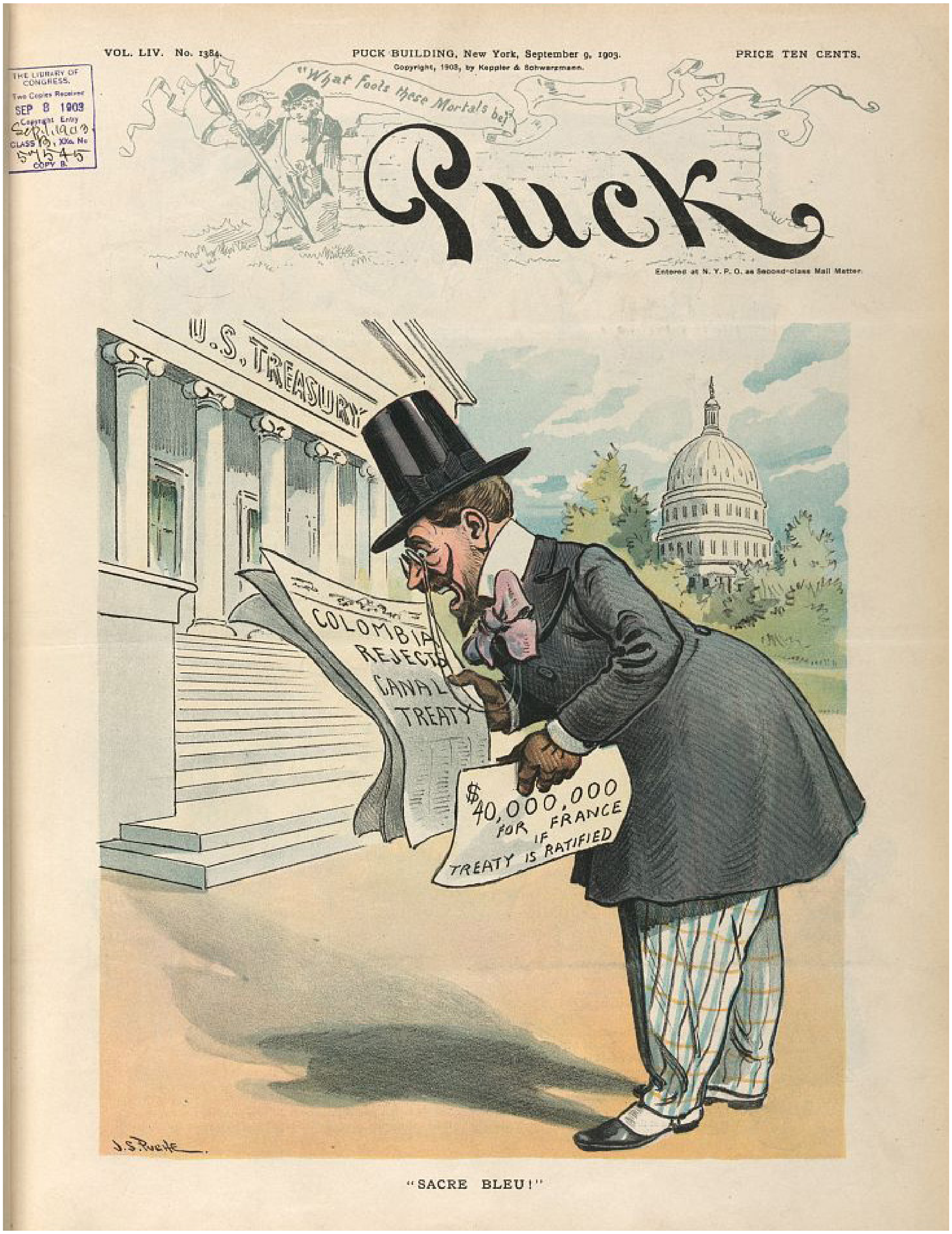

Figure 12: *"Sacre Bleu!"* - The image above on the cover of the September, 1903 issue of "Puck" after Colombia rejected the Hay-Herran Treaty that would have given the United States the rights to construct an isthmian canal. *Image courtesy of the Library of Congress.*

States, citing the terms of the 1846 Mallarino-Bidlack Treaty which gave them the right of way or transit across the isthmus of Panama unheeded, sent four warships to the Atlantic city of Colon. Their orders were to protect the Panama Railroad, but the real intentions behind the action were to prevent Colombian military forces from moving into Panama to put an end to the revolution. U.S. marines landed in the city and ensured that Panama's bid for independence was successful. On November 6, 1903, the United States formally recognized Panama as an independent nation.[98]

After the independence of Panama, Secretary Hay quickly prepared a treaty draft for U.S. rights to a canal. It was similar to the treaty that Colombia rejected, providing Panama sovereignty in a canal zone and giving them rights to protect the canal, with the agreement running 99 years. After receiving the treaty from Hay, however, Bunau-Varilla, one of the leading men from the French canal effort, reworked the terms to ensure canal neutrality. His revisions stated that the United States would protect Panama, but in return, the United States received "all the rights, power and authority within the zone… which the United States would possess and exercise if it were sovereign of the territory." The Canal Zone was also expanded from six miles wide to ten miles, and the United States was given "in perpetuity the use, occupation, and control" of the canal. On November 18, just twelve

[98] Suzanne P. Johnson, "An American Legacy in Panama: A Brief History of the Department of Defense Installations and Properties; The Former Panama Canal Zone, Republic of Panama," 8; Peter English, *Panama and the Canal Zone in Pictures*, (New York: Sterling Publishing Co., Inc., 1975), 32.

days after recognizing Panama's independence, Hay and Bunau-Varilla signed the treaty.[99]

Manuel Amador, Panama's first president, was not pleased since the treaty went against the Panamanian government's instructions to Bunau-Varilla for drafting a canal treaty. The Panamanian people and government protested, stating that the treaty was a renunciation of their sovereignty. However, rejection of the treaty meant that the United States might seize the land for the canal without a treaty, or the possibility of building the canal in Nicaragua instead, thus leaving Panama without U.S. protection which would potentially allow Colombia to retake the nation. In the end, Panama accepted the treaty as it had little choice. The treaty was later known in Panama as "The Treaty that No Panamanian Signed."[100] Although the Hay-Bunau Varilla treaty gave the United States rights to build the canal, it would become a deep source of controversy and dispute between the two nations throughout the twentieth century.

Construction and Sanitation

As work began on the canal, Roosevelt told American engineers and workers to "make the dirt fly." In 1904, Roosevelt appointed John F. Wallace as the Isthmian Canal Commission's chief engineer. Wallace provided water and sewer systems for his workers, as well as improved housing for the workers as a replacement for temporary housing left

99 Enscore et al., "Guarding the Gates: The Story of Fort Clayton – Its Setting, Its Architecture, and Its Role in the History of the Panama Canal," 1-1; Walter LaFeber, *The Panama Canal: The Crisis in Historical Perspective*, (New York: Oxford University Press, 1978), 37-38.

100 LaFeber, *The Panama Canal: The Crisis in Historical Perspective*, 38-39.

Figure 13: *Teddy Roosevelt at the Culebra Cut.* This photograph shows President Theodore Roosevelt operating a steam shovel at the Culebra Cut, Panama Canal. *Image courtesy of the Library of Congress.*

behind by the French. French equipment was also replaced with new, efficient American models in order to continue excavation of the canal. Soon into the construction effort, however, Wallace became frustrated with red tape that he needed to go through with the federal government in order to successfully carry out construction of the canal. The diplomacy that caused his frustration led to the resignation of Wallace in 1905.[101] Wallace was quickly replaced by a new Chief Engineer by the name of John Stevens. At the time,

[101] Hoffman, et al, *The Panama Canal: An Army's Enterprise*, 11.

workers were returning home due to insufficient pay, housing, unsatisfactory food and sanitation, as well as fear of disease. Stevens initiated improvements in these areas, but he too became frustrated with the regulation from Washington and was replaced by George Goethals. Goethals oversaw the Panama Canal for the remainder of its construction until it was completed and opened in 1914.

To successfully complete the canal without drastic setbacks, the United States needed to stop the spread of disease among workers in order to limit the amount of deaths that plagued the French effort. Chief sanitary officer William Gorgas oversaw the efforts to slow and prevent the spread of yellow fever and malaria. By draining low-lying wetlands such as ponds and swamps, using screens and mosquito netting, and quarantining ill workers, Gorgas successfully eradicated malaria and yellow fever from the region, possibly preventing thousands of additional deaths and allowing the construction of the canal to continue without the burden of disease.[102]

The construction of the canal required the damming of the Chagres river in order to create a large lake for ships to transit between locks. On the Atlantic side of the canal, Cristobal Harbor was constructed and a sea level channel was dredged to allow ships to access locks that would raise them eighty-five feet to newly created Gatun Lake. On the Pacific side, workers had to excavate through the Intercontinental Divide, a massive undertaking that required the removal of millions of tons of earth. The result was the

102 Hoffman, et al, *The Panama Canal: An Army's Enterprise*, 26-50.

Culebra Cut, also known as the Gaillard Cut during United States operation.[103] Locks were also constructed to raise and lower ships from a channel leading to Balboa Harbor on the Pacific side of the canal. Earth that was excavated during construction was used as landfill on mud flats on the Pacific side of the canal to create new land areas that would later be used for the construction of military installations to oversee canal defense.[104]

In the fall of 1913, the Culebra Cut was completed and flooded with water from Lake Gatun. The cut was completed when President Wilson, in Washington, pressed a button that detonated the dike in Panama which was holding back water in Gatun Lake from the Culebra Cut. Dredges continued working on the canal as it neared completion. On January 7, 1914, the *Alexandre La Valley* became the first ship to complete a transit of the canal. The outbreak of World War I overshadowed the canal's official opening, which was marked by the transit of the *SS Ancon* on August 15, 1914.[105] With the threat of war looming over the United States, the implementation of defense installations in the canal zone seemed more necessary than ever.

Militarization

The Hay-Pauceforte and Hay-Bunau-Varilla treaties did not explicitly grant the

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103 The Culebra Cut was renamed the Gaillard Cut after Colonel David DuBose Gaillard, a native South Carolinian and engineer at the Panama Canal Zone who led the excavation of the cut. Gaillard died from a brain tumor before the canal was completed. For more information on Col. Gaillard and his association with the Panama Canal, see Jon T. Hoffman et al., *The Panama Canal: An Army's Enterprise.*

104 Ryan, *The Panama Canal Controversy: U.S. Diplomacy and Defense Interests*, 20.

105 Hoffman et al., *The Panama Canal: An Army's Enterprise*, 73.

United States the right to fortify the Canal Zone, but they did state that the United States had liberty to "protect it against lawlessness and disorder." The possibility of fortification was left open, and was ultimately assumed by the United States due to Article Three of the Hay-Bunau-Varilla treaty which gave the United States all "powers, rights, and authority in the Canal Zone."[106] In November 1910, the Taft administration set up the Panama Fortification Board which proposed fortification schemes for the Atlantic and Pacific terminals of the Canal. During peacetime, the fortifications were to be manned by artillery companies and infantry regiments.[107] In 1911, the House of Representatives appropriated $2 million for the purpose of fortifying the canal. By August 1, 1914, an additional $12 million had been appropriated for the installation of defenses at the Panama Canal.[108]

Although protection of the canal by Naval blockade was no longer necessary since the canal was being fortified, the Navy was still placed in charge of protecting the sea approaches to Panama while the Army was placed in charge of maintaining land-based defense. With the establishment of canal fortification, Panamanian police were disarmed and no longer allowed to operate within the Canal Zone, essentially making the Canal Zone a sovereign U.S. territory without any Panamanian oversight. Throughout the following decades, this became a growing issue between the United States and Panama.

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106 Enscore et al., "Guarding the Gates: The Story of Fort Clayton – Its Setting, Its Architecture, and Its Role in the History of the Panama Canal," 1-4 through 1-5.

107 John Major, *Prize Possession: The United states and the Panama Canal, 1903-1979*, 158.

108 Enscore et al., "Guarding the Gates: The Story of Fort Clayton – Its Setting, Its Architecture, and Its Role in the History of the Panama Canal," 1-4 through 1-5; Johnson, "An American Legacy in Panama," 27.

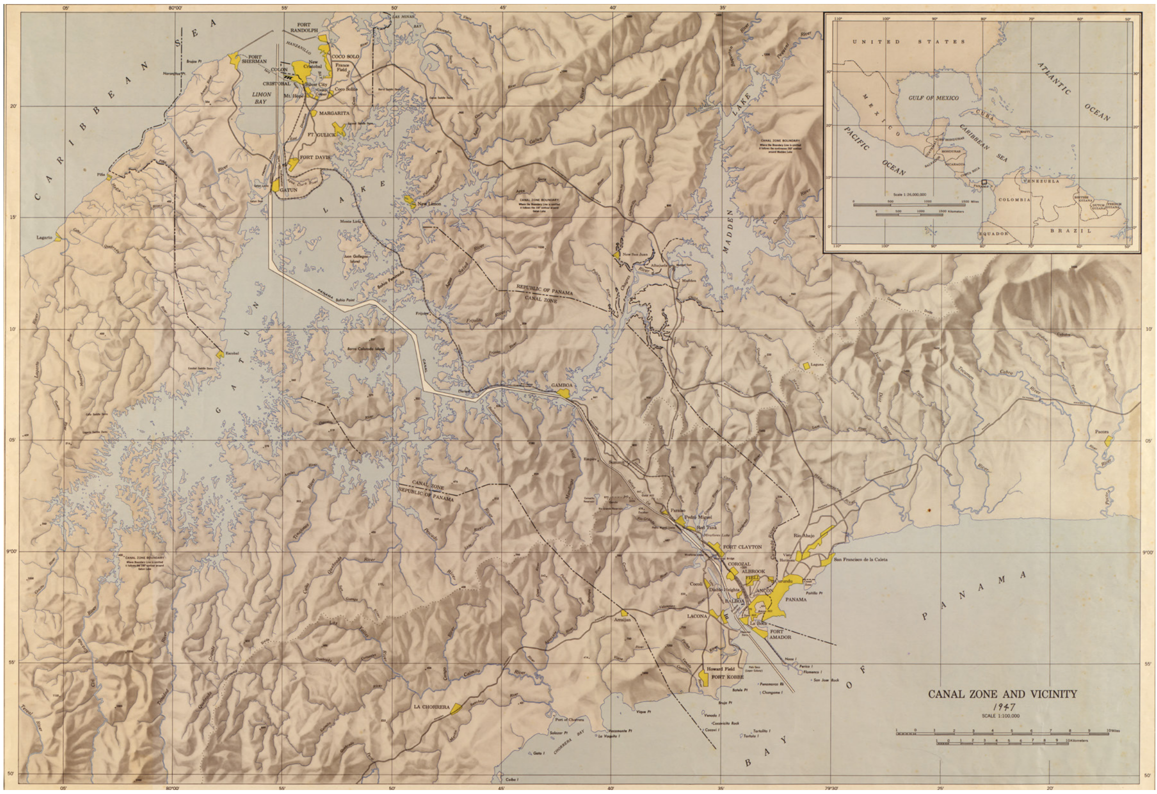

Figure 14: *Map of the Canal Zone and Vicinity, 1947.* This map shows various U.S. military installations from the period. *Image courtesy of the Library of Congress.*

As Army and Navy installations were established, federal funds were required for their construction. Appropriations in 1915 were allotted for the construction of Army barracks and quarters. Much of the initial construction made use of existing designs and materials specifications used during the period of canal construction. By summer 1915, nearly $15 million had been spent on Canal fortifications.[109] Military installations were built at both the Pacific and Atlantic terminals, as well as throughout the Canal Zone to protect the various locks and dams. On the Pacific side of the canal, installations included Fort Grant, a coastal artillery site named after the U.S. general and president, which was

[109] Enscore et al., "Guarding the Gates: The Story of Fort Clayton – Its Setting, Its Architecture, and Its Role in the History of the Panama Canal," 1-5 through 1-6.

built on landfill over the former mud flats. Installations on the mainland included Fort Amador, named after Panama's first president. Fort Clayton and Albrook Air Force Station were built during the 1920s to provide additional defense on the Pacific end. On the Atlantic side, Fort Sherman was constructed as a coastal battery. Fort Randolph was constructed on Margareta and Galeta islands, named after Major General Wallace F. Randolph.[110] In 1919 and 1920, Fort Davis and Coco Solo Naval Reservation were established to bulk up the defense of the Atlantic entrance to the Canal.[111]

With the development of aviation technology, the threat of aerial attack became a real possibility. Air defense of the Canal Zone was split between the Army and Navy in the form of reconnaissance flights and the installment of anti-aircraft batteries.[112]

Transition and Transfer

Throughout the twentieth century, the Canal remained an important component to trade and military transit for the United States. But growing tensions between the U.S. and Panama over ownership and operation of the canal were hurting the relationship between the two countries. This, in addition to the fact that by the mid-1970s the probability of

110 Hoffman, et al, *The Panama Canal: An Army's Enterprise*, 81.

111 For more information on the various military installations in the Panama Canal Zone, please see Appendix B: Index of United States Housing in the Panama Canal Zone. The various examples of housing from the Canal Zone are organized according to the installation to which they belonged. Prior to addressing each type of housing, a brief history of the installation is provided.

112 Hoffman et al., *The Panama Canal: An Army's Enterprise*, 79; Major, *Prize Possession: The United states and the Panama Canal, 1903-1979*, 284.

successfully defending the Canal from enemy attack was slim, it was decided that Panama's interests needed to be protected. Protests for full Panamanian independence, nationalism advocating for Panamanian control of the Canal, and social unrest, led to the agreement of a new treaty to establish a termination date for the treaty of 1903.[113]

On September 7, 1977, President Jimmy Carter and General Omar Torrijos signed the treaty, known as the Panama Canal Treaty and allied agreements, which terminated the 1903 agreement. Implemented on October 1, 1979, the treaty governed the operation, maintenance, and defense of the Panama Canal until December 31, 1999. Starting on implementation day in 1979, the Panama Canal Zone was no longer under U.S. jurisdiction as it reverted back to the Republic of Panama. Consequently, the Panama Canal Company and Canal Zone Government were dissolved as they were no longer necessary. The Panama Canal Commission was established as a new authority to operate and maintain the Canal. The commission was a mixed force of Americans and Panamanians, with the percentage of Americans comprising the force decreasing over the years until the transfer date. Although the U.S. was able to maintain several military installations in the region until the full transfer of the Canal, it was no longer solely in charge of protecting the Canal Zone. This duty became a joint effort in conjunction with the National Guard of the Republic of Panama.[114]

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113 Johnson, "An American Legacy in Panama: A Brief History of the Department of Defense Installations and Properties; The Former Panama Canal Zone, Republic of Panama," 10.

114 Enscore, et al, "Guarding the Gates: The Story of Fort Clayton – Its Setting, Its Architecture, and Its Role in the History of the Panama Canal," 7-1.

At noon on December 31, 1999, the Panama Canal Treaty of 1977 terminated and Panama assumed full control of operation, maintenance and defense of the Canal. The U.S. presence in the canal came to an end at that time, and all remaining U.S. personnel were soon removed. All Department of Defense property, including the various military installations, transferred to the Republic of Panama.[115] Rather than holding the Panama Canal in perpetuity, the United States controlled the canal zone for less than a century. Expansion of the Canal through the construction of new locks to accommodate larger ships has kept it up to date, allowing it to continue to function. Today, the Panama Canal remains as much a vital trade link between the Atlantic and Pacific as it did a century ago.

115 Enscore, et al, "Guarding the Gates: The Story of Fort Clayton – Its Setting, Its Architecture, and Its Role in the History of the Panama Canal," iii.

CHAPTER SIX:

UNITED STATES MILITARY HOUSING

U.S. Military Housing in the Early-Twentieth Century

During the late-nineteenth century, officers' quarters developed as a distinct building type at Army installations when troops were consolidated into larger permanent posts. Officers' quarters were stratified according to rank. Housing for high ranking officers was typically constructed around a parade ground while housing for Non-Commissioned Officers (NCOs) was often built separately away from the parade ground; enlisted men were housed in large barracks separate from both officers and NCOs. During the 1870s, the army began to develop standardized plans for base construction, including officer housing, which reflected trends in civilian architecture of the same period such as the Gothic Revival style.[116] Later popular styles that the army incorporated into housing design toward the end of the nineteenth century include Italianate and Queen Anne.

During the 1920s, the Army dealt with a housing shortage due to the fact that the Army Quartermaster Corps constructed few officer family quarters in the preceding years. The lack of adequate housing led to the enactment of Public Law 45 in 1926. This law granted the Secretary of War the ability to build new installations using money collected

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[116] R. Christopher Goodwin and Associates, Inc., "National Historic Context for Department of Defense Installations, 1790-1940," Volume II, (Frederick, Maryland: R. Christopher Goodwin and Associates, 1995), 307-371.

from the sale of nonessential posts, allowing the construction of new housing to alleviate the shortage. Additional funding from New Deal era programs allowed the Army and other branches of the armed services to further increase their construction programs. Military installations constructed during the 1930s were often larger than preceding examples, and buildings were organized differently. The location of officers' quarters during this period also shifted away from being centered around a parade ground, instead being formed into "neighborhoods around curving streets and parks."[117] This is how the Panama Houses are sited at the Charleston Navy Yard as they are constructed in the former Chicora Park grounds.

Unlike the Army, the Navy did not use standardized plans for housing, though Naval installations did at times reuse plans. During the 1930s, the Navy also implemented new construction programs at existing installations, often using appropriations from New Deal federal programs. The Panama Houses at the Charleston Navy Yard were built as a part of the interwar construction period which occurred during the 1930s through utilization of funds from these federal programs. Allegedly adopted from Army Quartermaster plans for housing in the Panama Canal Zone, their "low-pitched hipped roof, wide overhanging eaves, and porches were well suited to the hot-humid South Carolina climate."[118]

Housing constructed during this period was often designed to be comfortable and

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[117] Goodwin and Associates, Inc., "National Historic Context for Department of Defense Installations, 1790-1940," 372.
[118] Ibid., 373-374.

modern, reflecting the evolution of living standards for military personnel at the time.[119] Various designs were used in housing at installations throughout the United States; in the American South, Spanish Colonial Revival was often used.[120] Aspects of this style are reflected in the Charleston Navy Yard Panama Houses, specifically in the low-pitched hipped roof that originally featured clay tiles. The contemporary Charleston Naval Hospital also reflects some of these design elements.

Overview of Housing in the Panama Canal Zone

To build, operate, and maintain the Panama Canal after it was completed, the United States needed to provide housing for workers and servicemen. In order to accomplish this, the government set up an architectural department within the Isthmian Canal Commission. By 1906, the department developed plans for seventeen housing types that took into account the regional climate, available materials, sanitary department restrictions, and status of employees. The chief requirement among this was that the architecture be of a style suitable for a "damp, insect-infested, tropical country…with plenty of openings for ventilation."[121]

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[119] Comfort in this context is Human Thermal Comfort, which is defined by Dry Bulb Temperature and in some cases humidity. Thermal Comfort varies by geographic location – e.g., individuals from a warm, humid climate might find the comfort level in a colder climate to be disagreeable. Modern in this situation is in terms of living standards and the current architectural styles and tastes of the time period.

[120] Goodwin and Associates, Inc., "National Historic Context for Department of Defense Installations, 1790-1940," 373-375.

[121] Isthmian Canal Commission, "Annual Report of the Isthmian Canal Commission for the Year Ending December 1, 1906," (Washington, D.C.: Government Printing Office, 1906), 100–101.

Early in the construction of the canal, French colonial buildings remaining from the French attempt to build the canal were located and repaired, sometimes disassembled and moved to new locations where they were needed to house workers. This method was much more efficient at less than a third of the cost of constructing new housing for workers as the canal progressed. The migration of buildings took place largely during the 1910s, with over 55 moved in 1915.[122] This method of acquiring living quarters was the favored method for use by both civilians and military personnel.[123] New housing was also constructed, with many of the early types resembling French examples. These were raised above the ground on stone or concrete foundations and featured screened verandas to keep out mosquitoes while capturing breezes to help cool the structure.[124]

After the completion of the canal, permanent quarters were built for government and military employees. Congress appropriated funds for the construction of barracks, family housing, and other facilities for the Army and Navy at military installations throughout the Canal Zone. The types of quarters constructed was determined by a Board of Officers. A set of design guidelines were established that took into account durability as well as health regulations that were put in place by William Gorgas. These guidelines required buildings to be constructed of reinforced concrete with clay tile roofs. Studs were required to be left

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122 The Panama Canal, "Annual Report of the Governor of the Panama Canal for the Fiscal Year Ended June 30, 1915," (Washington, D.C.: Government Printing Office, 1915), 32.

123 Joseph Bishop, *The Panama Gateway*, (New York: Charles Scribner's Sons, 1915), 391.

124 Suzanne P. Johnson, "An American Legacy in Panama: A Brief History of the Department of Defense Installations and Properties; The Former Panama Canal Zone, Republic of Panama," (Fort Clayton, Panama: Directorate of Engineering and Housing, 1994), 19.

exposed on the interior in order to make them rat proof by preventing the rodents from living and breeding in the walls. Screened in porches and windows also made the buildings mosquito proof, helping to prevent disease. Ultimately, these guidelines contributed to the development of the Canal Zone building type.[125]

The U.S. government provided housing for all employees associated with the canal, included the families of employees. Families moving to the canal zone meant an increase in population, necessitating additional housing and other facilities required for the various communities. Schools, hospitals, and town sites were constructed to meet these needs.[126] After the canal was completed, the U.S. government began to move away from the reuse of French buildings and the construction of temporary housing in favor of permanent structures and communities meant to house personnel left to operate, maintain and defend the canal.[127]

Panama Canal Zone Architecture as a Building Type

Architectural styles found in Panama include Spanish colonial and French colonial styles, as well as tropical architecture typical of the locale.[128] Components of these styles were incorporated into the vernacular design of housing and structures built by the U.S.

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125 Johnson, "An American Legacy in Panama," 20.

126 Johnson, "An American Legacy in Panama," 23; Edith Crouch, *Architecture of the Panama Canal Zone: Civic and Residential Structures and Townsites*, (Atglen, PA: Schiffer Publishing Ltd, 2014), 13.

127 Crouch, *Architecture in the Panama Canal Zone*, 13.

128 Panamanian Vernacular Architecture of the indigenous people is typically constructed of wood frame with a straw roof. These structures are sometimes elevated above ground.

government in the Canal Zone. Design for military barracks and family quarters followed the types provided by the Army Quartermaster Corps. Styles that were already approved by the Isthmian Canal Commission were adapted by the Board of Officers responsible for determining the types of quarters used. Many of the permanent buildings constructed after the completion of the Canal were durable buildings constructed with concrete foundations to help prevent building degradation.[129]

Living quarters were located on the second floor while storage, servant's quarters, and garages were on the ground level.[130] This is the same spatial hierarchy used in the plans of the CNY Panama Houses are organized, with the exception of Quarters S and T. The foundation and ground level of these buildings are constructed of concrete columns and beams. Exterior walls are composed of hollow blocks finished with stucco, and roofs of red Spanish tile.[131] Similarly, the CNY Panama Houses feature a reinforced concrete foundation and ground floor structure with hollow block walls that fill the bays between the concrete columns. The ground floor is also finished with stucco, similar to the buildings from the Canal Zone. Although the later iteration of the CNY Panama House did not feature a tile roof, the original design used in 1937 did. From the application of building materials to the spatial organization, the designs for housing in the Canal Zone are clearly analogous to the design of the CNY Panama House. One of the primary differences, however, is that

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[129] Crouch, *Architecture in the Panama Canal Zone*, 335.
[130] Ibid., 30, 44-47.
[131] Ibid., 353-366.

many of the later buildings constructed in the Canal Zone are assembled at all levels using reinforced concrete and hollow tile, while the Charleston design only features reinforced concrete on the ground floor, with the second level built using timber frame.[132] Single family bungalows designed as officers' quarters in the Canal were constructed of wood frame supported on concrete pillars. This design featured an exterior stair which led to a porch space that opened into the living quarters on the second floor. The living quarters contain three bedrooms, two bathrooms, a living room and dining room, as well as a back kitchen with an exterior stairway.[133] Although the plans of these spaces are slightly different, they are the same as those on the second floor of the Charleston Panama Houses from 1937 and 1938, including the back stair off the kitchen.

The method of construction and design of the vernacular architecture in the Canal Zone was largely influenced by the tropical climate of Panama which often has very high humidity. Throughout the year, temperatures typically range from 80 to 90 degrees Fahrenheit (26.6° to 32.2° C.) during the day to the 70s at night (approximately 21° to 26° C.). The rainy season in Panama runs from May through December with sun, clouds and rain alternating on an almost daily basis. Rain occurs nearly every day during the rainy season, which can take a toll on wood and other building materials such as iron that are

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[132] This is not to say that all housing types in the Panama Canal Zone were constructed exclusively of reinforced concrete and hollow tile. There are many types of housing that were constructed using wood framing with the ground level, foundation or footings constructed of concrete, similar to the Charleston Navy Yard Panama Houses. See Appendix B for additional details on housing examples from the Panama Canal Zone.

[133] Crouch, *Architecture in the Panama Canal Zone*, 371.

susceptible to corrosion. This led to the use of concrete as the primary building material due to its durability compared to wood.[134]

Climate guided the development of various building features that were incorporated into the design. These features include window blinds, jalousies, screened porches or verandas, and raised foundations to help facilitate air circulation throughout the building.[135] Additional methods of ventilation include slatted overhead openings in interior walls. Doors in many of the buildings had louvered transoms to improve air circulation. Numerous windows were incorporated into all sides of the buildings for increased cross-ventilation.[136] All of these design elements were integrated into the architecture for maximum passive cooling.

Heavy rains in the region led to the development of window hoods or roof projections at intermediate floors meant to protect windows and entryways from rain. These projections developed into a continuous pent roof known as a "mediagua" or "media agua" which shed water from openings when it rained and blocked direct sunlight while still illuminating the interior to help keep the building cool.[137]

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[134] Susan I. Enscore et al., "Guarding the Gates: The Story of Fort Clayton – Its Setting, Its Architecture, and Its Role in the History of the Panama Canal," (Champaign, IL: U.S. Army Corps of Engineers, 2000), 2–7 through 2–8.

[135] A jalousie is a blind or shutter with adjustable horizontal slats or louvers that admit light and air while excluding sun and rain. "Jalousie," *Merriam-Webster*, accessed March 1, 2017, https://www.merriam-webster.com/dictionary/jalousie

[136] Enscore et al., "Guarding the Gates," 2–10.

[137] Crouch, *Architecture in the Panama Canal Zone*, 31, 47; Enscore et al., "Guarding the Gates," 2–8.

Housing Comparison | Canal Zone and Navy Yard

The CNY Panama Houses and U.S. housing in the Canal Zone must be compared in order to fully understand the correlation between them. This places the Charleston Panama Houses within the wider international context of which they are a part by using real examples of housing designs from the Panama Canal Zone. Due to their unique characteristics compared to other architectural types in the South Carolina Lowcountry, the CNY Panama Houses represent a distinct architectural form. Among these characteristics are the cast-in-place concrete columns used in the construction of the ground floor, wood frame construction on the second floor, casement windows, wide overhanging eaves, hipped roof with louvered ridge vents, and an open floor plan with a T-shaped central living space. These characteristics are particularly important when comparing the Panama Houses to the Canal Zone housing they were derived from.

Architecture in the Canal Zone changed overtime, primarily in terms of construction materials rather than in overall design. During the construction years of the canal and the following two decades, wood frame construction set in concrete footings was the standard building method. As permanent town sites and military installations were developed, however, reinforced concrete supporting wood frame became the primary construction method because it limited decay.

An example of one of the earlier housing types is Type 17, a type of Officers' Quarters constructed at Balboa Heights and Fort Amador. Both of these installations were

Figure 15: *Quarters Type 17, Front Elevation, Fort Amador, PCZ. Image courtesy of the Library of Congress.*

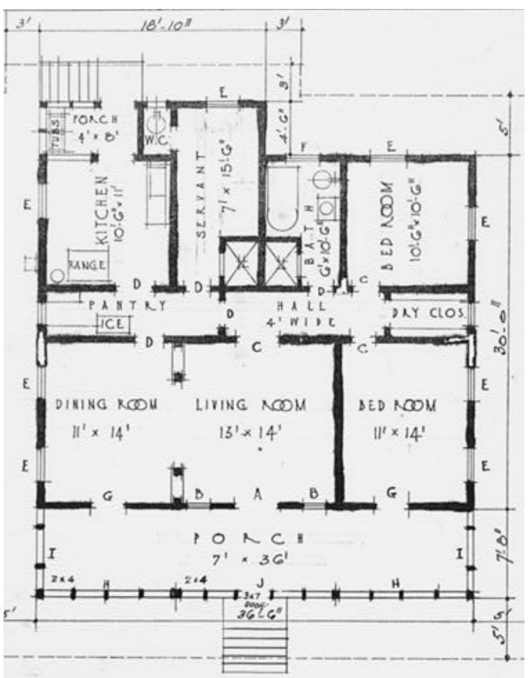

Figure 16: *Quarters Type 17, Floor Plan, 1916. Image courtesy of the Library of Congress.*

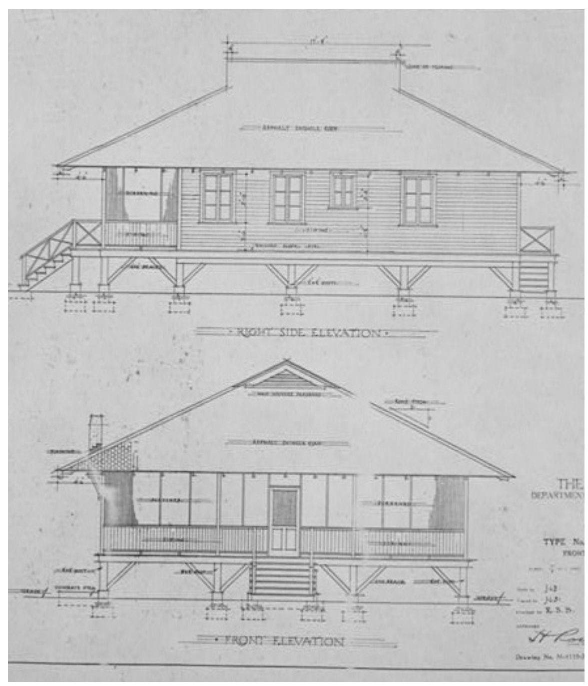

Figure 17: *Quarters Type 17, Front and Side Elevations. Image courtesy of the Library of Congress.*

established in 1914, the same year that the Canal was completed. Revised architectural drawings of the Type 17 Quarters date to March 1916. The original drawings likely date to at least the previous year before this set of revised drawings was made. Constructed relatively early after the completion of the Canal, these quarters required little excavation, with concrete footings supporting wooden posts serving as the foundation. Standard for the time, the footings support the building, elevating it several feet off the ground rather than an entire story like many of the later Canal Zone designs or the CNY Panama Houses. This construction method allowed many of these houses to be built much more quickly and efficiently.

A full length screened–in porch runs along the front façade, an architectural design feature that the French used on many of their structures. In later Canal Zone quarters, the porch is integrated into the body of the house, serving as an extension of the interior space with large bands of windows rather than simply being a screened-in exterior space. This is how the Panama Houses were designed, with the open space comprising the top of the ‘T’ on the main living floor acting as the “living porch.” The term living porch is labeled on architectural drawings of other Canal Zone housing types from the period. Additional exterior features of Type 17 include casement windows, an exterior lateral stair at the rear that accesses the kitchen, overhanging eaves with exposed rafters, and a hipped roof with louvered ridge vents. These features are shared with the CNY Panama Houses. One difference is in the roofing material – Type 17 has a corrugated metal roof while the

Panama Houses originally had tile, now asphalt shingle.

On the interior, the spatial layout of Type 17 deviates from the plan of the Panama House. The porch does run along the front of the house, but rather than connecting the porch to the rear of the building, the central hallway runs parallel to the porch. The living and dining space, as well as the master bedroom, are accessed from the porch. These same rooms open into the hallway on the opposite side. At the rear of the house are the kitchen, an additional bedroom, and servant's quarters. While the dining room and living room are open to one another, the rest of the plan is more traditional in its spatial organization than later designs for Canal Zone quarters. This could correlate to the date when the building was designed and constructed, as the designs for housing changed and developed over time in part to make them further suitable for the climate.

Although established during the early 1930s, another housing type which used concrete footings and wood supports is located at Albrook Air Force Station, a military installation at the Pacific Terminus of the Canal. This housing type listed as Civilian Quarters was likely built during the post-construction phase of the Canal, as its exterior differs from the earlier French housing and temporary housing provided for workers during the construction phase. Albrook AFS was developed during the early 1930s, so it is unlikely that these quarters pre-date that period. The photograph of the Civilian Quarters is dated 1937, at which point the buildings are likely several years old. Concrete footings provide protection for the wooden foundation posts that support the main floor of the building.

While many types that use this construction method only raise the main floor several feet above grade, this example raises the building an entire story to provide additional space for a ground floor underneath the main floor. While the construction method for the ground floor differs from the CNY Panama Houses which use reinforced concrete, the quarters still retain the partially-open ground floor, a standard feature of the Panama Houses. Additionally, the civilian quarters appear to be square in plan and have a hipped roof with wide overhanging eaves and exposed rafters. Although the roofing material is different, and there is no indication of louvered vents at the roof ridge, these elements coincide with the Charleston Panama Houses. These quarters also have an exterior lateral stair which runs from the corner of the house, although in this case it is of wood construction.

One difference between the two is that the designs for the Panama Houses feature

Figure 18: *Civilian Quarters, Albrook AFS, PCZ, 1937.* Also found on page 173, Figure B.1. *Image courtesy of the National Archives and Records Administration.*

larger floor plans than the Civilian Quarters at Albrook. This is evident from the number of windows per side, but made clear when using the child in the picture for scale. From the photograph, it is difficult to ascertain the type of window used in the Civilian Quarters due to the fact that they are screened over. If they are casement windows, they would have to be able to swing inward as the screens would prevent them from swinging outward. It is possible that since screens are used, they are sash windows. The appearance and plan of the interior is unknown due to the fact that this is the only photograph of the Civilian Quarters at Albrook AFS that was identified during the research process, and no corresponding architectural drawings were found. Despite these limitations, the design of the Civilian Quarters is clearly tied to the CNY Panama Houses through their shared architectural features.

Also located at Albrook Air Force Station are the Company Officer's Quarters and Field Officer's Quarters. Both types are identical in method of construction and architectural features while differing in size and plan. Although no drawings were identified to provide an approximate date of construction for these quarters, they probably date to the mid-1930s. This date was determined based off a similar design for Field Officers' Quarters at Fort Clayton that were completed in January 1933. Like the Panama Houses, these quarters are two-stories in height with the first floor serving as the primary living space above the ground floor. The ground floor for both quarters types is semi-open to allow air flow. Enclosed bays on the ground level are slightly recessed, similar to the Panama

Houses. The bays on the Officer's Quarters types here, however, have additional decorative elements. At the top corners of the openings, an ornamental cyma mold has been added. The cyma mold, as well as the tile roof, is representative of the Spanish Colonial Revival elements that are present in many Canal Zone buildings. The exteriors of the buildings have a rough, white stucco finish. This deviates slightly from the Panama Houses which have a smooth stucco finish applied to the exterior of the ground floor. Although both types do have hipped roofs with louvered ridge vents like the Panama Houses, they have smaller cross hipped roofs that protrude from the main roof form due to the fact that they are not square in plan.

Windows in both types are large single paned windows rather than casements. The photographs make it unclear whether they are operable, although at the time when they were built they would likely have to be operable due to the fact that the buildings were constructed before the advent of air conditioning. It is possible that the original windows were removed and replaced during later decades when many quarters in the Canal Zone were updated with air conditioning. Part of retrofitting quarters for air conditioning included removing screened in sections of porches and installing windows to fill them in and make them air-tight to prevent the escape of conditioned air. This likely occurred with the Company Officer's Quarters on the first floor, as indicated by a photograph showing windows filling bays of the living porch that have spaces above them that appear as if they have been filled in. Prior to this, they were likely screened-in in the same manner that

Figure 19: *Company Officers' Quarters, Street View, Albrook AFS, PCZ. Image courtesy of the Library of Congress.*

Figure 20: *Company Officers' Quarters, Interior, Albrook AFS, PCZ.* This photograph shows part of the living porch. Note the grated transom over the door and the jalousies in the windows. These windows were likely screened-in when the building was constructed. *Image courtesy of the Library of Congress.*

Figure 21: *Field Officers' Quarters, Exterior, Albrook AFS, PCZ. Image courtesy of the Library of Congress.*

Figure 22: *Field Officers' Quarters, Interior, Albrook AFS, PCZ.* Note the louvered panel doors and grated transoms that allow ventilation and air flow. *Image courtesy of the Library of Congress.*

portions of the ground floor are, as indicated through photographs of the building.

The windows currently in place are fitted with jalousies in order to provide light while blocking direct solar energy. When these quarters were constructed, it was important that they be open to the exterior to allow air circulation on the interior. Interior doors were typically louvered with bar transoms. Partition walls also had bar transoms to provide additional circulation. While these elements took away a degree of privacy they afforded additional comfort. Although the CNY Panama Houses do have an open floor plan and large expanses of casement windows, they lack the louvered doors and transoms that provide additional air circulation. It is likely that such features were deemed unnecessary since Charleston has a subtropical climate, meaning that although summers have relatively high temperatures and humidity, winters are typically cool.

While no architectural drawings were available to compare the plans of these two types of quarters with the Panama Houses, photographs provide enough information to draw some comparisons. The photographs show that both types have living porches connected to a perpendicular central living space. This area is open and serves as both the living and formal dining space. Additional photographs of the Company Officer's quarters show the kitchen and butler's pantry opening off the central space, likely flanking a bedroom. On the opposite side from the kitchen are two bedrooms with a shared bathroom, meaning that the Company Officer's Quarters and the CNY Panama Houses likely share a very similar floor plan.

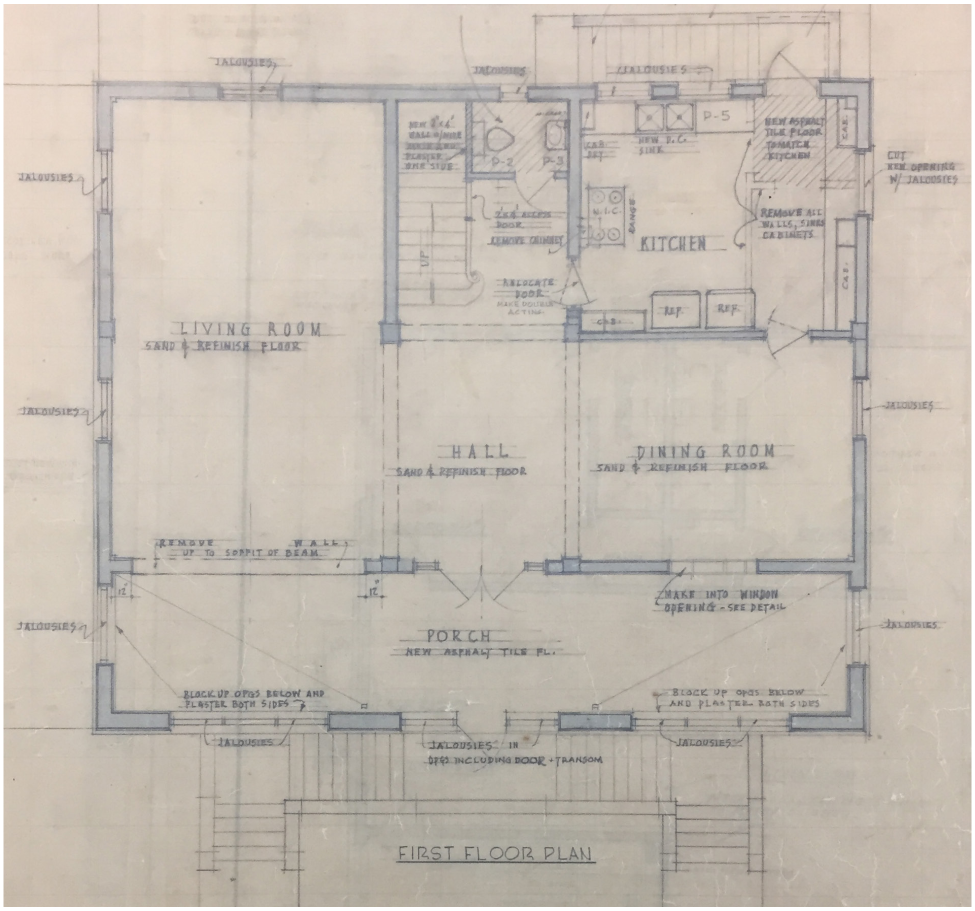

Figure 23: Field Officer Quarters' No. 20, First Floor Plan, Fort Amador, PCZ. Image courtesy of the National Archives and Records Administration.

Two quarters types located at Fort Amador are the Commanding Officer's Quarters and Field Officer Quarters' Nos. 20 and 38. Both the CO and FO Quarters follow the same design. This means that they were all constructed following the same set of standardized plans that were likely produced by the Army Quartermaster for use at military installations throughout the Canal Zone. No elevations were identified for these quarters, but the floor plans for each are identical. The earliest drawing is dated 1914, with drawings for rehabilitation of the buildings dated 1933, a relatively early Canal Zone housing type built soon after the Canal was completed. Specifications on the drawings indicate that they are constructed using reinforced concrete with wood framing used for the openings and roof system. The roof is likely hipped and clad with tile as is the standard for Canal Zone architecture.

Plans are provided for the first and second floors of each of the Quarters with the first floor accessed from the front by a double stair to the main entrance. This indicates that is a ground floor but a plan for one is not provided. The main entrance at the top of the stair opens onto the porch that runs the full length of the main façade. A central stair hall runs through the center of the building on the first floor from the porch to the rear of the building. To the left of the central hall is the living room; the dining room and kitchen are on the opposite side. The second floor differs with three bedrooms lining the front façade, all of which open onto the second floor porch. A fourth bedroom, two bathrooms and a store room comprise the rear portion of the second floor along with the stair. The second floor deviates completely from the design of the CNY Panama Houses in terms of floor plan and the fact that the Panama Houses do not have a second floor. The first floor, however, does share some commonalities. The porch and stair hall form a T-shape that comprises the primary circulatory space. All of the windows appear to be French windows based on the way they are portrayed in the floor plan. Opening inward, these windows are possibly screened on the outside in the same manner as the porch to allow air circulation while preventing mosquitoes from getting inside. An exterior lateral stair at the rear of these quarters opens into a small entry, similar to the Panama Houses.

Type 7 is another housing design used in the Canal Zone that bears many similarities to the Panama Houses. The design for Type 7 Quarters dates to 1939, and architectural drawings indicate that it was used at Mount Hope in the Canal Zone. Square in plan, Type 7 is two stories which includes the ground floor and first floor. The ground floor is largely open with only a servant's room and storage as the interior space. Remaining open areas serve partially as garage space. Constructed using reinforced concrete pillars on a slab footing foundation, the quarters have a wood-framed hipped roof. The roof has the standard widely overhanging eaves which the roof plan indicates are left exposed. The elevations of the building, at only three bays wide, are similar to the front and rear facades of the Panama Houses. Large bands of windows constitute the majority of the space in the exterior walls. Two exterior lateral stairs provide access to the kitchen and primary living space.

In this instance, the central living space is L-shaped rather than T-shaped. On the side of the building that shares space with the lower portion of the "L" is a bedroom and kitchen. Rather than being positioned at the rear corner of the building like many other Canal Zone buildings and the CNY Panama Houses, the kitchen is positioned in the center of the building along the left side. Adjacent to the long vertical side of the L-shaped central space are two bedrooms that share a bathroom, the same way in which the Panama Houses are arranged. One difference is that the Type 7 quarters are smaller in plan at only 37 feet by 33 feet compared to the Panama Houses, which are 50 feet square. On account of less

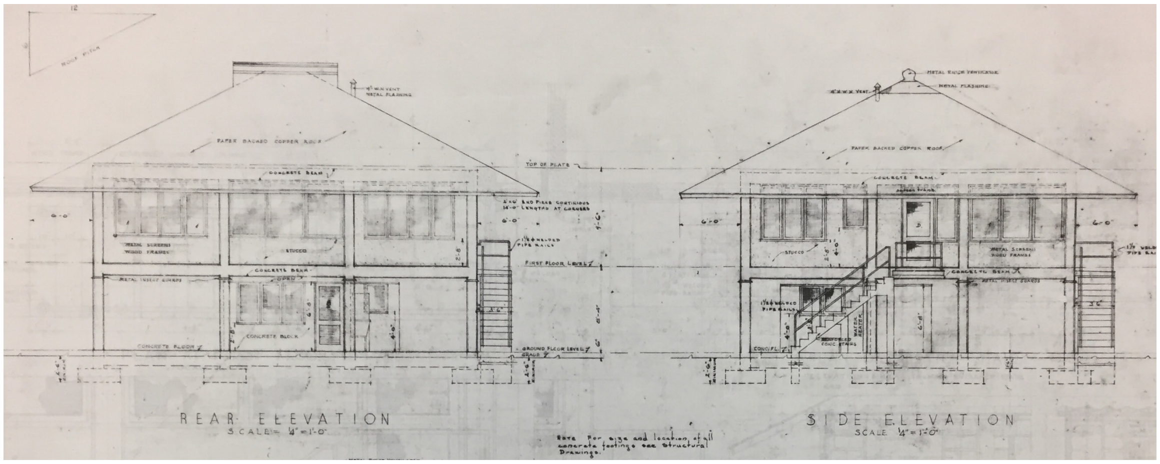

Figure 24: *Single CO Quarters Type 7, Rear and Side Elevations, Mount Hope, PCZ, 1939. Image courtesy of the National Archives and Records Administration.*

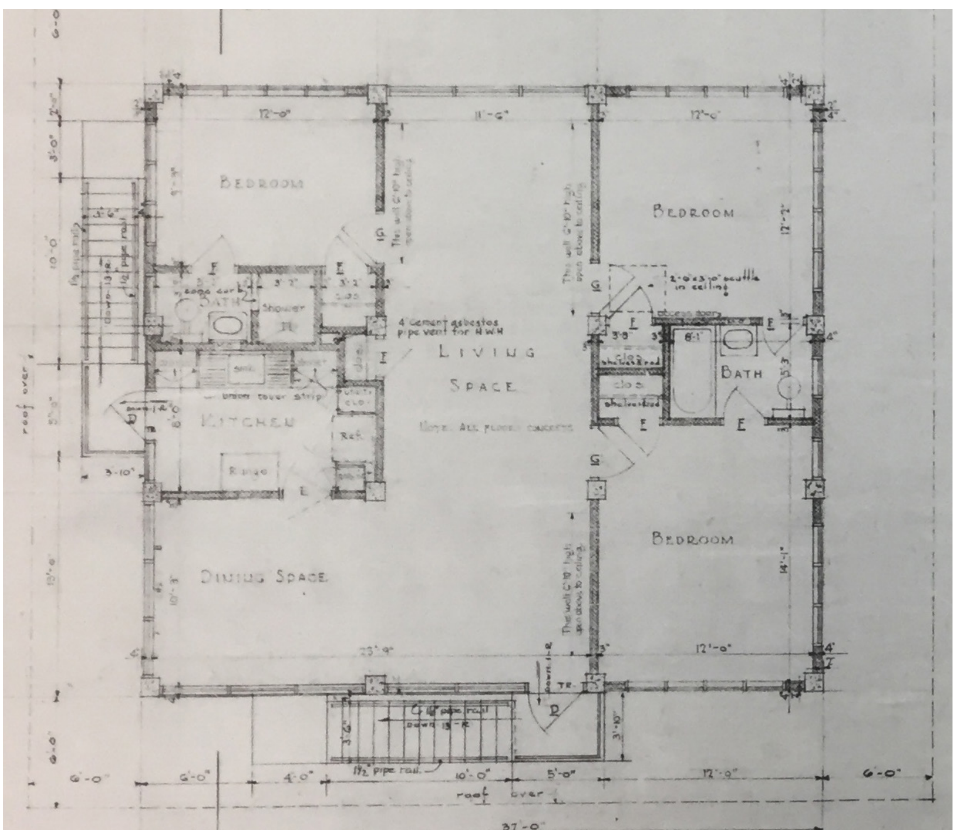

Figure 25: *Single CO Quarters Type 7, First Floor Plan, Mount Hope, PCZ, 1939.* Note *Image courtesy of the National Archives and Records Administration.*

available square footage, it could be that some of the central living space was forgone in order to keep the bedrooms at an adequate size. Less primary living space would explain the L-shaped central space. Despite these differences, the Type 7 quarters remain similar to the Panama House with clear correlation in design and plan.

Two designs that are similar to Type 7 are the Single Field Officers' Quarters Types 2 and 5. Both are variations of a standardized set of drawings completed in 1939, likely the same set that Type 7 is a part of. They are similar to Type 7 in terms of their construction materials, exterior appearance, and plan which includes an L-shaped open central space used as the dining and living rooms as well as the porch. Larger than Type 7 by approximately 10 feet per side, Types 2 and 5 have an extra bedroom. Additionally, the kitchen has been moved to one of the rear corners of the building, similar to the Panama Houses. One of the primary differences between Types 2 and 5 and the design of the first iteration of the CNY Panama Houses is that in addition to the kitchen on the main floor, there are also four bedrooms rather than three, with one of these bedrooms occupying one of the corners of the building which changes the central plan from a T-shape to an L-shape. Aside from these differences, these quarters share the same similarities with the Panama Houses that Type 7 shares. Between types 2 and 5 themselves, they are nearly identical with the exception of the plan. The plans for each type are exactly the same except that one plan is mirrored two ways in order to make it appear different. This provides variation within the types of the standardized design, creating a "new" building design without technically creating anything new. Establishing variations such as these helped cut down on design costs and allowed for greater time and construction efficiency.[138]

Of the various designs of Canal Zone housing located during the research process, two types of quarters bear the closest resemblance in plan to the Panama Houses. One is a standardized design for Field Officers' Quarters designated Type 1; no location was provided with the architectural drawings of this type. The second is a standardized design for Single CO Quarters Type 3 located at Fort Sherman. Both types are dated 1939 and are part of the same group of standardized designs that Types 2, 5 and 7 belong to. Type 1 is unique due to the fact that the drawings indicate it is to be built into a hill or terrace which makes it appear as one story when viewing the primary elevation, and two when viewing the rear. Both types are constructed using reinforced concrete footings, with reinforced concrete pillars and slabs serving as the structure for each floor. The bay and partition walls are likely masonry construction. By this time masonry was used as the primary building material for both floors rather than wood frame or a combination of cement and wood frame since it is the most resistant to decay.[139] Wood framing was used in buildings of concrete construction for window and door openings and roof framing.

Large bands of casement or single-pane windows of various sizes are used throughout both designs on the first floor exterior. Each type has a hipped roof with wide,

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138 For more information on Single Field Officers' Quarters Types 2 and 5, including architectural drawings, see Appendix B.

139 Quarters constructed using reinforced concrete for the ground floor and wood frame for the first floor similar to the CNY Panama Houses were still constructed during this time but with less frequency.

overhanging eaves; these appear to be lacking louvered ridge vents as indicated by the drawings. Square in plan, the ground floor for Type 3 houses the servant's quarters and storage space, the rest is open to allow air circulation to help cool the house. Type 1 also houses the servant's quarters and storage space, but in this design less room is available for air circulation since the building is constructed into a hillside. This means that the side at the higher elevation only has a small crawl space below the ground and first floor.

At the first floor, both types have the signature T-shaped plan serving as the space for the dining room, living room, and porch; this plan is shared with the Panama Houses. Flanking one side of the central portion of the open space in Type 1 are two bedrooms which share a bathroom located between them. One of the bedrooms opens directly into the bathroom while the other bedroom opens into a small hallway that must be crossed to access the bathroom; the hallway runs perpendicular to the central living space and an exterior stair. On the other side of the central living space is the kitchen which is also accessed from the exterior by a lateral stair. Two additional bedrooms occupy the remaining space on the first floor. Aside from an additional bedroom, Quarters Type 1 is very similar to the plan of the first iteration of the Panama House which has three bedrooms instead of four on the first floor. It is similar to the later version seen in Quarters S and T at the Charleston Navy Yard which does have four bedrooms on the first floor. Quarters S and T, however, do not have a kitchen on this floor. In this manner, Type 1 partially resembles both versions of the Panama House design.

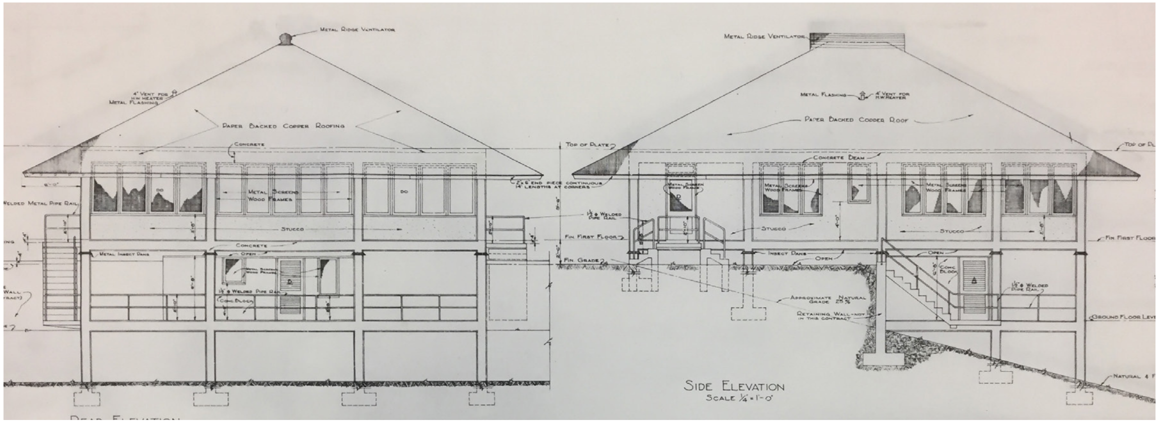

Figure 26: *Field Officer's Quarters Type 1, Rear and Side Elevations, 1939. Image courtesy of the National Archives and Records Administration.*

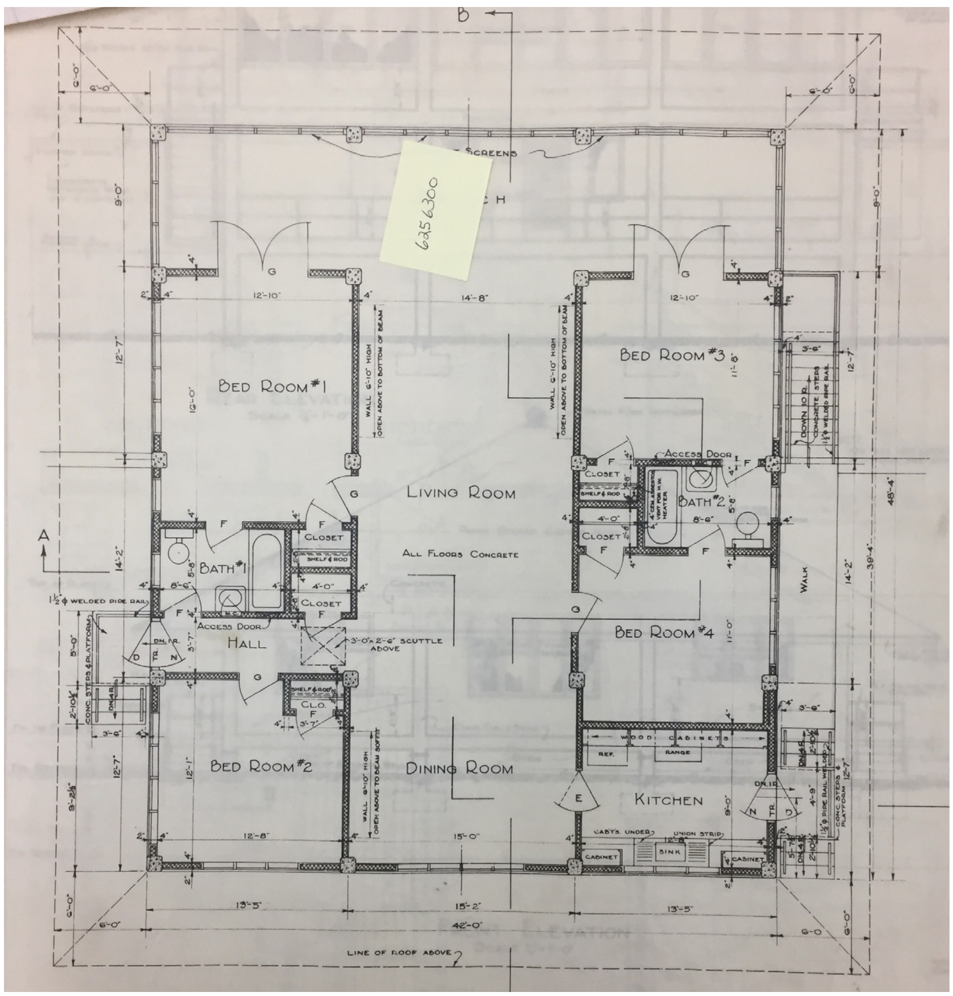

Figure 27: *Field Officer's Quarters Type 1, Floor Plan, 1939. Image courtesy of the National Archives and Records Administration.*

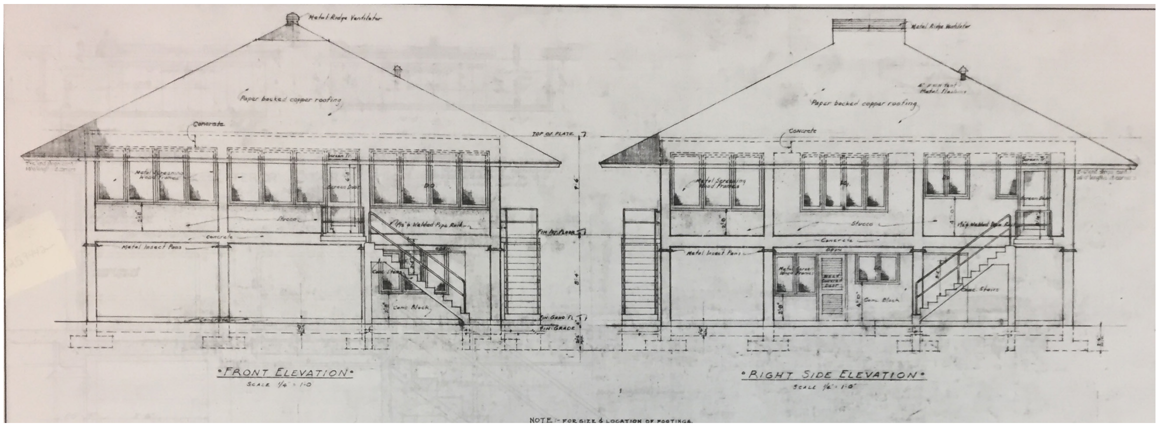

Figure 28: *Single CO Quarters Type 3, Front and Right Side Elevations, Fort Sherman, PCZ. Image courtesy of the National Archives and Records Administration.*

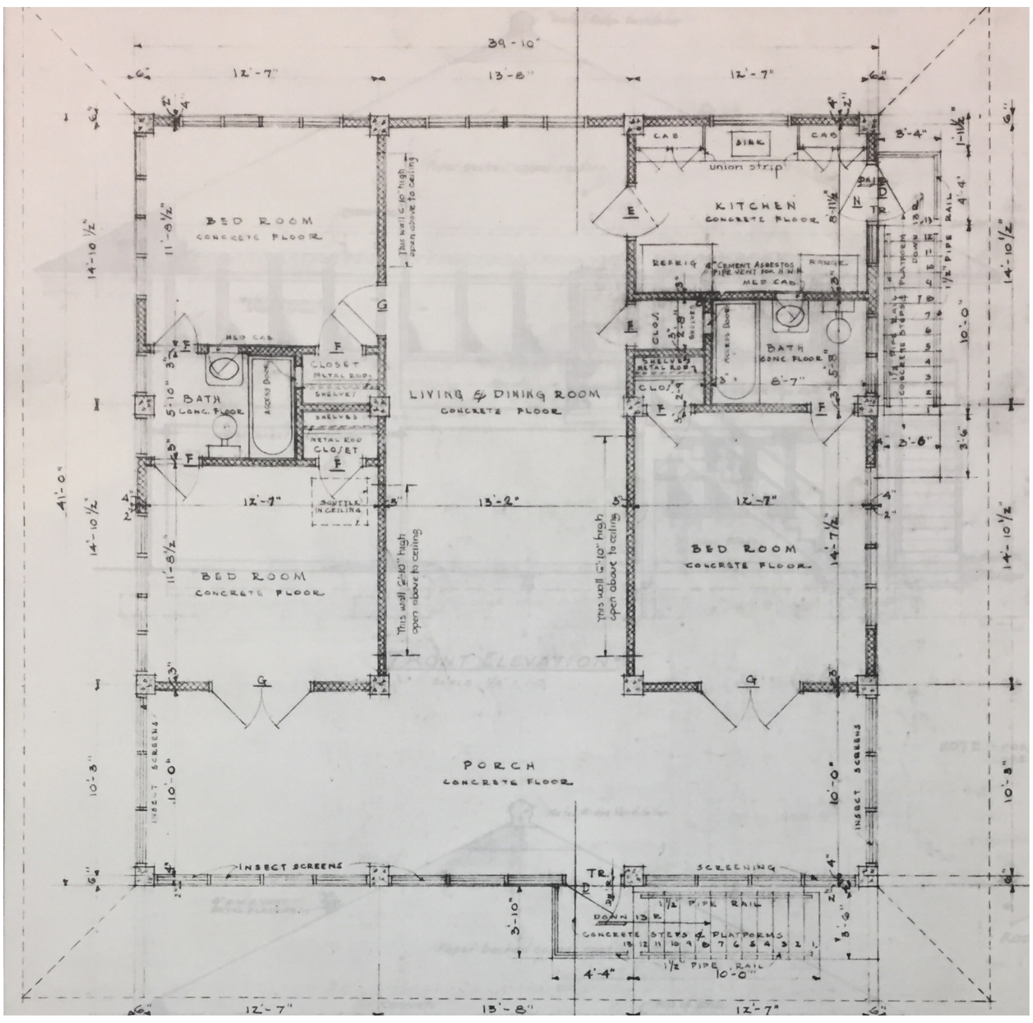

Figure 29: *Single CO Quarters Type 3, First Floor Plan, Fort Sherman, PCZ. Image courtesy of the National Archives and Records Administration.*

Type 3 differs slightly in plan from Type 1. Rather than have a small hallway between two bedrooms that provides an additional point of entry from the exterior to the central living space, Type 3 has an exterior lateral stair that accesses the living porch. On one side of the central space are two bedrooms which open into a central bathroom that they share. On the opposite side is a bedroom with an additional bathroom, and a kitchen at the rear corner. The kitchen is accessed from the side of the building by an exterior stair. Despite being approximately ten feet shorter per side, Type 3's plan is nearly identical to the plan for the initial design of the Panama House at the Charleston Navy Yard. The first Panama House design at the CNY has a T-shaped plan with three bedrooms, two bathrooms and a kitchen arranged in the same manner. The most noticeable differences are that the Panama House has a butler's pantry attached to the kitchen. The second distinct difference is a small additional hallway that runs between the kitchen and third bedroom that connects the central space to the second bathroom. The adjacent bedroom opens into this hallway to access the bathroom rather than directly accessing the bathroom itself like the design for Type 3. It must be noted, however, that the CNY Panama Houses are slightly larger, which means more floor area was available in the for additional spaces such as the hallway. The nearly identical floor plan makes Type 3 the most analogous example to the Panama House of American Housing in the Canal Zone.

Despite their obvious likeness to architecture in the Canal Zone, the Panama Houses do have one building feature incorporated into their design that differentiates them from the architectural type they were derived from. Although Charleston does have hot and humid summer months, winters are typically cool, and can get cold on occasion. This is contrary to Panama's climate which remains hot and humid all year round. Due to the cooler weather during the winter months, the Charleston Panama Houses each have a single fireplace and chimney incorporated into their design. The fireplace is centered in the living area that runs from the living porch to the rear of each Panama House. This building element is the only clear component added to the CNY Panama Houses that the original housing in the Canal Zone does not have.

The various examples of U.S. quarters from the Canal Zone compared with the CNY Panama Houses clearly demonstrate that there is a strong connection between the designs. This connection directly ties the Panama Houses and their location back to the Canal Zone, as the myriad of similarities indicate the Panama House designs were directly imported from the Canal Zone. Their construction method, fenestration, and architectural details show that they are undoubtedly a derivative of Canal Zone architecture. The climatic adaptive features of Canal Zone housing, which include an open or partially open ground floor, reinforced concrete construction, casement windows, wide overhanging eaves, and various other elements for passive cooling, all contributed to the success and wide use of the design throughout the region for nearly a century. It is possible that the design was imported and used at the Charleston Navy Yard due to the success of the Canal Zone architectural style in alleviating the discomforts of the Panamanian climate.

CHAPTER SEVEN:

ANALYSIS

Climatic Adaptation

In Chapter Six, examples of U.S. housing in the Canal Zone were presented in order to explore them as an architectural type, utilizing housing in the region from various time periods to demonstrate evolutionary form. Each housing type represents a key moment in the history of the Canal Zone architectural type. The purpose was to provide examples from the region to place the CNY Panama Houses in context as a borrowed design while also analyzing the vernacular elements that comprise the preceding form. These discernible vernacular components that serve as identifying characteristics of Canal Zone architecture were largely developed as climatic adaptations to cope with the hot, humid regional conditions.

Located in a tropical region, Panama has distinct wet and dry seasons. The wet season begins in May and runs through December. Additionally, the Panamanian climate is humid with high temperatures averaging in the eighties (degrees Fahrenheit) that remain relatively constant throughout the year due to the country's proximity to the equator. These high levels of humidity and warm temperatures are very similar to the climate in Charleston during the summer months. During this period in the year, temperatures in Charleston tend to average in the upper seventies and eighties (° F).[140] In hot-humid regions such as these, the climate is uncomfortable primarily due to the high humidity rather than the warm or hot temperatures. One of the ways to ameliorate the humidity and the temperature of the climate and to make building occupants comfortable is to maximize natural ventilation and limit direct sunlight on building facades through climatic building features.[141] Adaptive features in Canal Zone architecture that provide an increase in natural ventilation include large expanses of operable windows, louvered doors, ventilated attics, open floor plan, and an elevated floor. Other features such as wide, overhanging eaves and mediaguas decrease direct solar gain on building facades and through apertures.

Climate-integrated designs can take advantage of positive climatic attributes in the region where they are located in order to limit negative attributes that cause modern notions of discomfort. Important aspects of climate integrated design include controlling solar gain, exploiting winds and breezes, and using efficient materials and building design to effectively deal with climate.[142] Of these features, ventilation through passive cooling techniques is one of the most commonly used design tools in warm to hot climates. Passive cooling applies to buildings that are architecturally designed to react to regional

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[140] Edith Crouch, *Architecture of the Panama Canal Zone: Civic and Residential Structures and Townsites*, (Atglen, PA: Schiffer Publishing Ltd, 2014), 31; Susan I. Enscore et al., “Guarding the Gates: The Story of Fort Clayton – Its Setting, Its Architecture, and Its Role in the History of the Panama Canal,” (Champaign, IL: U.S. Army Corps of Engineers, 2000), 2-7 through 2-8.

[141] Baruch Givoni, “Climatic Aspects of Urban Design in Tropical Regions,” *Atmospheric Environment, Part B, Urban Atmosphere* 26, no. 3 (September 1, 1992), 397–398.

[142] Akubue Anselm, “Building with Nature (Ecological Principles in Building Design),” *Journal of Applied Sciences* 6, (2006), 960.

climatic conditions in order to create comfortable conditions for occupants through natural rather than mechanical means. This method works to prevent outdoor heat from entering buildings while also transferring indoor heat outside in order to keep the building as cool as possible.[143]

Although not typically applied to modern buildings in the region, passive cooling techniques are acceptable in regions where they can ameliorate conditions to make interior spaces more comfortable. Using a psychrometric chart, a standard comfort zone can be visually represented according to dry bulb temperature (DBT), wet bulb temperature (WBT), and relative humidity. The comfort zone is defined as the range within which occupants of a building are satisfied with their surrounding thermal conditions.[144] As indicated in Figure 30, using natural ventilation to add air motion within a building can extend the comfort zone to higher temperatures. This means that natural ventilation, a form of passive cooling, is an effective way to reach more comfortable indoor temperatures and humidity levels. It may also be one of the only passive cooling strategies available in hot, humid climates where temperatures remain relatively constant.[145] Air movement through ventilation can easily cool a building if it is efficiently designed with integrated architectural elements that

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143 Ardalan Aflaki et al., "A Review on Natural Ventilation Applications through Building Façade Components and Ventilation Openings in Tropical Climates," *Energy and Buildings* 101, (August 15, 2015), 154.

144 A psychrometric chart is a graphical representation of the psychrometric processes of air. Psychrometric processes include physical and thermodynamic properties such as dry bulb temperature, wet bulb temperature, humidity, enthalpy, and air density. Information from: "Psychrometric Charts," *Autodesk Sustainability Workshop*, accessed April 25, 2017, https://sustainabilityworkshop.autodesk.com/buildings/psychrometric-charts

145 Benjamin Stein and John S. Reynolds, *Mechanical and Electrical Equipment for Buildings*, (New York, NY: John Wiley & Sons, Inc., 2000), 48, 57.

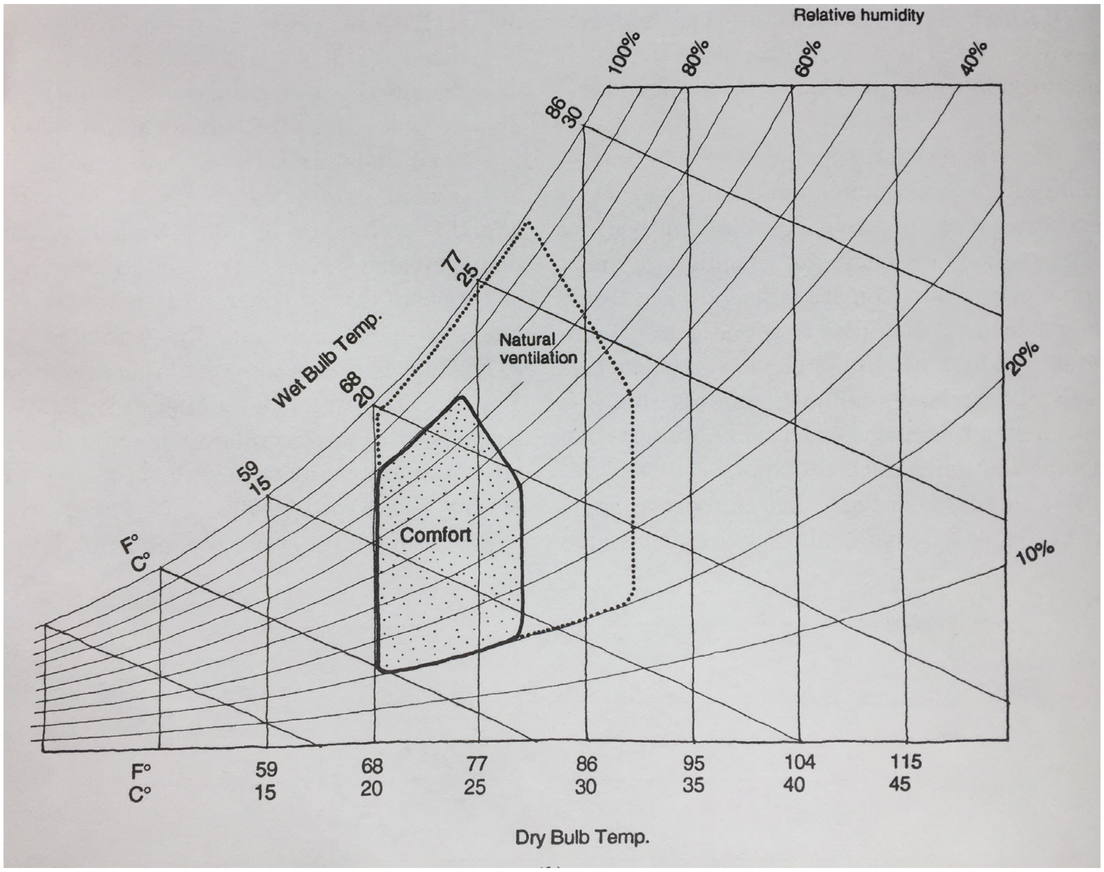

Figure 30: *Psychrometric Chart.* This chart shows the correlation between natural ventilation and comfort. These are the suggested boundaries of outdoor air temperature and humidity within which indoor comfort can be achieved through natural ventilation. Benjamin Stein and John S. Reynolds, *Mechanical and Electrical Equipment for Buildings*, (New York, NY: John Wiley & Sons, Inc., 2000), 46.

improve ventilation. Building orientation, façade design, form, massing, and location and size of apertures, can all influence natural ventilation. One of the ways in which natural ventilation can occur is when wind is blocked by a building mass which influences the air pressure. This creates higher wind velocities on the windward side of the building and lower velocities on the leeward side. The pressure differential provides ventilation to the building when apertures are open to allow air to flow inside and cool the interior. This air flow can be in the form of single-side ventilation and double-side or cross ventilation.

Single-side ventilation occurs when wind moves in and out of a building through apertures located on the same side. Cross-ventilation differs in that it allows wind velocities to move into a building from one side and out through another, allowing air to circulate completely through a building.

Corridors that run the length of a building are an effective part of a floor plan that can help create or increase cross-ventilation.[146] They also allow spaces closed to the exterior to ventilate if they open onto the corridor, as air moves into the spaces and back out again through an opening into the room, creating single-side ventilation as an extension of cross-ventilation. Natural ventilation and other passive cooling techniques are conclusively one of the dominant ways to increase cooling and comfort within a building, including tropical climates.

Due to the climatic similarities between Charleston's warmer summer months and the climate of Panama, the hypothesis is put forward that the Panama House was imported as a vernacular building type and adopted by the Charleston Navy Yard in the 1930s due to its climatic adaptive design for the Canal Zone. The Panama House designs are similar in terms of materials, architectural features, and floor plan to many examples of Canal Zone housing. Construction using a concrete foundation with hollow tile walls and reinforced concrete structure in the ground floor and timber frame for the second floor is analogous to Canal Zone housing. The large bands of casement windows, roof type and roof features

[146] Aflaki et al., "A Review on Natural Ventilation Applications through Building Façade Components and Ventilation Openings in Tropical Climates," 154–155.

provide further emphasis to this connection, ultimately appearing as if the Panama Houses were constructed in the Canal Zone and subsequently picked up and dropped into the landscape at the Charleston Navy Yard.

It is highly implausible that importation of this design was mere coincidence. The notion that the designs for the Panama Houses were created for use at the CNY without prior knowledge of Canal Zone housing is highly doubtful. Rather, it is much more probable that a ranking Naval Officer stationed at the Navy Yard had prior experience in the Canal Zone where he encountered the vernacular architectural type of U.S. housing in the region. Multiple sources state that the designs of the buildings were built in accordance with Panama's climate; the success of the design led to their subsequent reuse in the region throughout the twentieth century.[147] The suitability of the design in the hot-humid isthmian region likely led to the Officer recommending its use at the Navy Yard due to Charleston's hot and humid summers. Such reasoning would explain the development of the Panama House design from Army Quartermaster plans for housing in the Panama Canal Zone. The only reason that this social hypothesis cannot be verified is due to the lack of written

[147] For sources that address how the climate played a role in the development of the design of Canal Zone architecture, please see the following: Edith Crouch, *Architecture of the Panama Canal Zone: Civic and Residential Structures and Townsites*, (Atglen, PA: Schiffer Publishing Ltd, 2014), 31 & 47; R. Christopher Goodwin and Associates, Inc., "National Historic Context for Department of Defense Installations, 1790-1940," Volume II, (Frederick, MD: R. Christopher Goodwin and Associates, 1995), 374; Susan I. Enscore et al., "Guarding the Gates: The Story of Fort Clayton – Its Setting, Its Architecture, and Its Role in the History of the Panama Canal," (Champaign, IL: U.S. Army Corps of Engineers, 2000), 2-7 through 2-10; Susan I. Enscore et al., "The Quarry Heights Military Reservation in the Republic of Panama: Historical Documentation of the Installation and Bldg. 23," (Champaign, IL: U.S. Army Corps of Engineers, 1996), 16; Suzanne P. Johnson, "An American Legacy in Panama: A Brief History of the Department of Defense Installations and Properties; The Former Panama Canal Zone, Republic of Panama," (Fort Clayton Panama: Directorate of Engineering and Housing, 1994), 19.

primary source material and documentation that would account for the origination of the design at the Navy Yard.[148] Despite this, the similarities between the climates of the two regions makes it exceedingly likely that climatic considerations played a role in the adoption and reuse of the design at the Navy Yard.

Charleston's Climate

Climate Consultant was used to gather climatic data for Charleston.[149] The program provides hourly and monthly means of data in the form of numerical and graphic representations for the location of interest, showing various patterns of the climate. Climate Consultant also takes the outdoor climatic data and translates them into interior comfort, providing guidelines for building design suited to the climate. For the chosen location, the program produces a general Weather Data Summary with standard information including average hourly radiation, illumination, temperature, and humidity. For the Panama Houses,

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[148] During the research period conducted for this report, attempts were made to locate sources regarding the social history of the Panama Houses and who or what led to their importation and use at the Charleston Navy Yard. Unfortunately, no sources regarding this information were located at the various archives and repositories in the Charleston area. Architectural and design drawings of the Panama Houses and cultural resource and conditions reports conducted just prior and after base closure were the only sources located that provide information on the Panama Houses in detail. Primary source material regarding the Panama Houses is very limited.

[149] Climate Consultant is a simple, graphic based computer program that helps users understand their local climate. It uses data from various weather stations made available by the Department of Energy at no cost and translates the data into graphic displays. It plots the data in a manner that is easy to understand and takes the data to create design guidelines specific to a location which allows users to create energy efficient and sustainable buildings. University of California, Los Angeles created and runs the program. Information from Climate Consultant 6.0, (Los Angeles, CA: UCLA Energy Design Tools Group, 2014), accessed 15 March, 2017, http://www.energy-design-tools.aud.ucla.edu/climate-consultant/. Climate Consultant was developed by the UCLA Energy Design Tools Group. Copyright © 2014 The Regents of the University of California. All Rights Reserved.

Monthly Means	March	April	May	June	July	August	
Dry Bulb Temperature (Avg. Monthly)	60	64	71	78	81	80	**Degrees F**
Dew Point Temperature (Avg. Monthly)	47	51	63	69	72	72	**Degrees F**
Relative Humidity (Avg. Monthly)	66	67	77	77	77	76	**Percent**
Wind Direction (Monthly Mode)	190	200	190	200	190	190	**Degrees**
Wind Speed (Avg. Monthly)	54	56	63	69	73	76	**MPH**

Table 1: *Monthly means of weather data from March through August for Charleston, SC. Data obtained from Climate Consultant 6.0*

however, average monthly DBT, humidity, wind direction and speed are the most important elements to consider based on principles that establish ventilation as the main passive cooling strategy. The program measures comfort based on a psychrometric chart where relative humidity and temperature influence human thermal comfort (see Table 1). Aside from the general Weather Data Summary, four different comfort models can be chosen in order to obtain detailed climatic data. Due to the analysis of the Panama Houses as a climatic adaptive building type with features that utilize passive cooling techniques, the Adaptive Comfort Model in ASHRAE Standard 55-2010 was chosen. This differs from the other models because it does not include mechanical cooling methods in its analysis.[150]

150 Aside from the Adaptive Comfort Model – the last model in the list of options provided – Climate Consultant provides three additional models from which you can choose to analyze climatic data for a given location. The first is the California Energy Code Comfort Model, 2013, which is the default model that the program is set to. The second option provided is ASHRAE Standard 55 and Current Handbook of Fundamentals Model. The last additional option is the ASHRAE Handbook of Fundamentals Comfort Model up through 2005.

Using the Adaptive Model, Climate Consultant provides data on adaptive comfort through natural ventilation for a chosen region, in this case, Charleston. This data includes the maximum mean monthly outdoor DBT of the climate at 81.4° F (27.4° C), and the comfort high / maximum operative temperature for the climate at 83.9° F (28.8° C).[151] Because the adaptive comfort model runs with the understanding that mechanical cooling is not being utilized, air velocity in the building is to be controlled by opening and closing windows. Using the adaptive model, Climate Consultant provides a list of design guidelines for the best building strategies that apply specifically to Charleston's climate. Ten of the guidelines are as follows, they are listed in order according to their importance for consideration in building design for the region:

1.Good natural ventilation, which "can reduce or eliminate air conditioning in warm weather, if windows are well shaded and oriented to prevailing breezes."

2. To facilitate cross ventilation, locate door and window openings on opposite sides of the building with larger openings facing up-wind if possible.

3. Screened porches and patios can provide passive comfort cooling by ventilation in warm weather and can prevent insect problems.

4. Use open plan interiors or louvered doors to promote natural cross ventilation.

5. Shade to prevent overheating, open to breezes in summer.

151 It is important to note that these numbers do not represent highs or lows, but averages. This is crucial to know for the Charleston Climate where temperatures can reach into the 90s or higher on occasion during summer months. Climate Consultant was developed by the UCLA Energy Design Tools Group. Copyright © 2014 The Regents of the University of California. All Rights Reserved.

6. Traditional passive homes in warm humid climates used high ceilings and tall operable (French) windows protected by deep overhangs and verandahs.

7. Low pitched roofs with wide overhangs work well in temperate climates.

8. In wet climates, well ventilated attics with pitched roofs work well to shed rain and can be extended to protect entries, porches, verandas, and outdoor work areas.

9. If soil is moist, raise the building high above ground to minimize dampness and maximize natural ventilation underneath the building.

10. Window overhangs or operable sunshades can reduce or eliminate air conditioning.

These ten guidelines are important because they are largely applicable to the CNY Panama House designs. Screened porches, open plan interiors, relatively high ceilings, operable casement windows, low pitched roofs with wide overhangs, and a raised second floor with a partially open ground floor, are all design elements of the Panama House to which these standards apply. Despite having these various climatic adaptive features incorporated into their design, the ability of the Panama houses to adequately capture breezes and provide natural ventilation remained to be seen. To assess their efficacy in utilizing passive cooling to alleviate thermal discomfort, the designs of the buildings were run through simulations modeling air flow.[152]

[152] These design guidelines come directly from Climate Consultant 6.0; they do not all come from the first ten guidelines provided in the list, instead representing those that are directly applicable to the Panama Houses. For a full list of design guidelines ranked by importance as provided by Climate Consultant for buildings utilizing adaptive comfort strategies in Charleston, please see Appendix C.

Air Flow Simulations

Models of the two Panama House designs were assessed through simulations in order to determine their adeptness in natural ventilation to provide comfort. Quarters M represents the original Panama House design while Quarters T represents the 1941 version. These simulations of the two Panama House designs were completed in conjunction with simulations for two additional Navy Yard officer's quarters – Quarters X and Y – which serve as the control group, providing additional data to determine with greater accuracy the effectiveness of the Panama House design in the Charleston climatic setting. Three simulations were completed for each of the four buildings, comprising one simulation for each floor and a third simulation for each building as a unit. Simulations were run through Autodesk Flow Design, a computer program that acts as a virtual wind tunnel that provides visualization of airflow through and around buildings. This program is an effective tool for analyzing moving air and how it can be affected by building design.

To ensure that the simulations for each building were accurately conducted in accordance with one another, a set of parameters were applied to each one. Charleston's climate is very warm and humid during the late spring and summer months, during which time natural ventilation can be an effective tool. Winters can get relatively cold; it is unlikely that natural ventilation would be used for the majority of time during winter months as heating is usually required. Taking these climatic factors into consideration, each simulation was run in accordance with the average prevailing wind direction for the

Figure 31: *Aerial Image, Officers' Quarters Historic District, Charleston Navy Yard.* This aerial photograph shows Panama Houses shaded in blue and the control buildings shaded in red. The original four Panama Houses constructed along the Cooper River can be seen at the right edge of the photograph. *Image courtesy of Google Maps; annotated by author.*

months of March through August, as they constitute the months during which temperatures increase and reach their peak in Charleston. The average monthly wind direction for each of these months is 190°–200°, or approximately between south by west and south-southwest.[153] Each model was arranged in accordance with its true position on site at the Navy Yard, with the wind direction hitting each building from the prevailing wind direction. The wind speed in all of the simulations was set at 32.808 feet per second (9.99 m/s). All simulations were assessed using several different visualization methods in order

[153] This is not meant to imply that prevailing winds only travel between 190° and 200° during these months. These numbers represent the average prevailing winds; wind can travel in multiple other directions during these months. For the purposes of this analysis, the winds were set in the same direction for uniformity to ensure that results are accurate between one another.

to fully understand air movement through the buildings.[154] It is important to note that the absence of trees and other vegetation, as well as contextual buildings and landmarks in each model places a degree of limitation to the simulations since these objects are not taken into account as obstacles to wind movement. This is primarily applicable to buildings located in the western end of the Navy Yard rather than those along the riverfront. Additionally, contextual elements that are not modeled – including the riverfront, and trees for shading – are features that can also aid in cooling the building in addition to passive cooling methods such as natural ventilation.

Panama House Type I – Quarters M

Quarters M, constructed according to the initial Panama House design, is one of the first four Panama Houses built at the east end of the Officer's Quarters Historic District along the Cooper River waterfront. The building is oriented approximately east-northeast, with the main façade facing the river. Due to its orientation, the average prevailing wind

[154] Several methods are available in Flow Design to view how air moves around and through buildings. Planes are used, both vertical and horizontal, to represent how air moves through a building. This is especially effective when running the analysis and viewing the model from plan view. Planes are represented with either shades or vectors, which can be toggled back and forth. Both are useful because one may provide information that the other does not. The third method is the use of flow lines. These are especially useful when running analysis on models of complete buildings rather than individual floors or models with the roof removed. Settings for flow lines include count, speed, size, and length, all of which can be changed depending on the model being run through the simulation. Flow lines and planes can be run in 2D or 3D mode. In all three simulation methods, colors are used to represent wind velocities - warm colors represent higher wind velocities and cool colors represent lower wind velocities.

Figure 32: *Quarters M, Charleston Navy Yard.* Perspective photograph showing the rear (west) and side (south) elevations of the building. *Photograph by author.*

currents do not hit any of the building facades directly, instead coming in at an angle.[155] Prevailing wind currents first hit the building's northeast corner and flow across the windward north and east facades before wrapping around the west and south facades, which fall on the leeward side of the building where there is lower air pressure.

The ground floor of Quarters M, features mixed levels of air flow. Along the main façade of the building, air flows through the three open bays of the screened-in porch before exiting through the single open bay of the porch at the south end of the building.

[155] The primary reason that Quarters K, L, M, and N are oriented on site in this manner is because the Cooper River is the main focus of orientation. It was important to have the buildings oriented with their front facades facing the river for both aesthetic purposes, as well as for taking advantage of breezes coming off of the river.

This creates a well ventilated exterior space that can provide thermal comfort and relief; it can also serve as an outside extension of the interior living space. The orientation of the building in association with the wind direction appears to limit wind flow from the porch to the interior of the building through the main entrance off the porch which opens into the entry foyer on the ground floor. The two adjacent rooms – mechanical room and one of two servant's rooms – south of the main entrance do receive airflow as the wind currents move through the porch and hit the ground floor façade. Windows into each room allow air currents to enter and circulate. The mechanical room is centrally located, which limits the level of airflow compared to the adjacent maid's room which is open to the exterior on both the east and south facades. This means that the mechanical room primarily uses single-side ventilation as air from the porch enters and exits the room through the single window located in the east wall (as a rarely occupied space, thermal comfort is not vital here). On the other hand, the maid's room is able to cross ventilate as air moves into the room from the porch east window before exiting through the entryway in the south wall.

Lower wind velocities on the leeward side of the building still provide a degree of ventilation for spaces at the rear. Figures 33 and 34 show how air moves through the garage in single-side ventilation, entering one car port and exiting out through the other along the same side. The simulation also shows that the second maid's room on the ground floor, located at the southwest corner of the building, is ventilated through cross-ventilation as shown in Figure 34. This image uses vectors rather than shades to depict air movement.

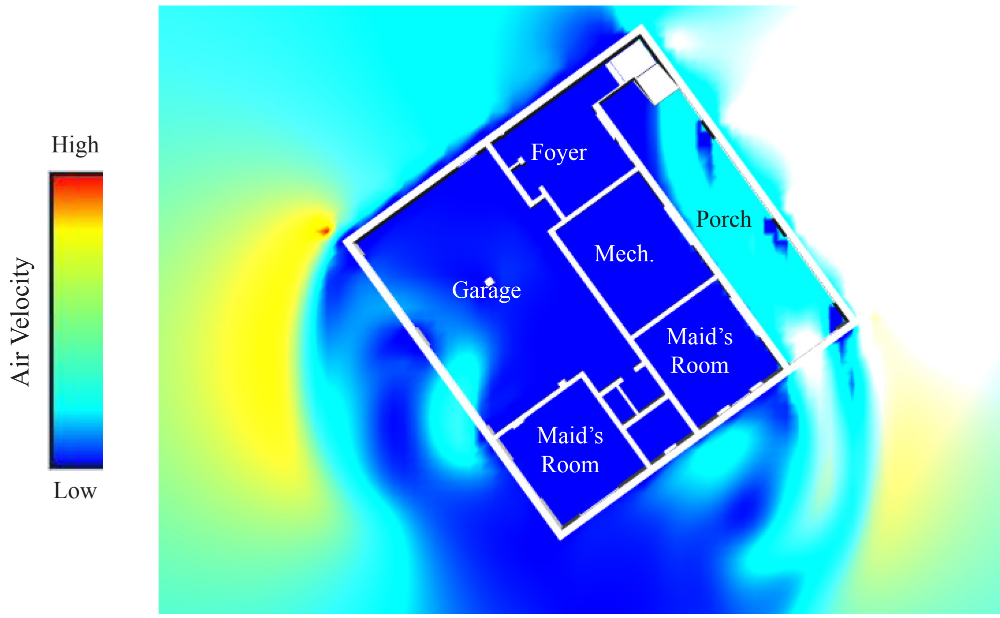

Figure 33: *Plan view of Quarters M, ground floor - Flow Design simulation using shades.* This particular image uses a shaded horizontal plane to depict airflow, which is directed from the top of the image to the bottom. The top-right portion of the picture shows air moving through the screened-in porch, while single-side ventilation can be seen moving air through the garage at the left. *Screenshot from Flow Design.* As indicated by the color key, warm colors represent high wind velocities while cool colors represent low wind velocities

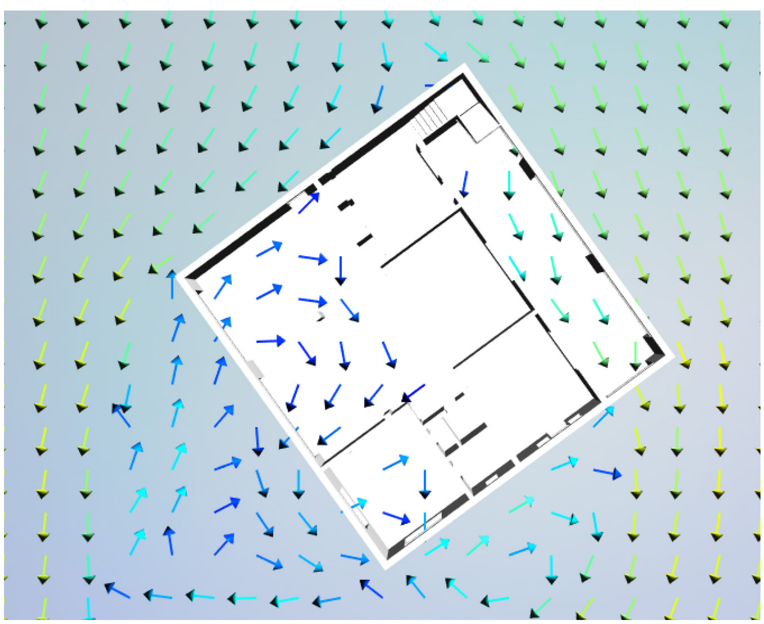

Figure 34: *Plan view of Quarters M, ground floor - Flow Design simulation using vectors.* Note the movement through the maid's room at the bottom corner of the building. *Screenshot from Flow Design.*

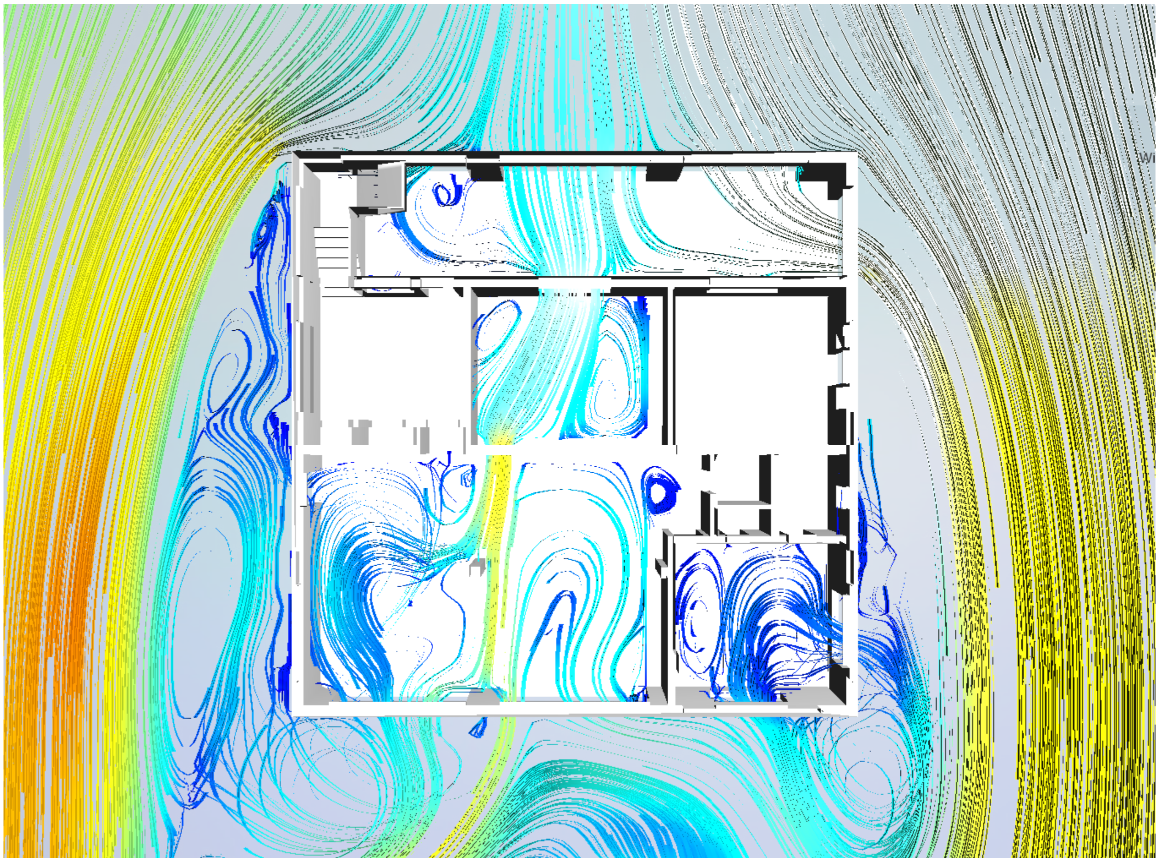

Figure 35: *Plan view of Quarters M, ground floor - Flow Design simulation using flow lines.* This image depicts the movement of air through the ground floor when the wind direction hits the front of the house directly. This is meant to emphasize how natural ventilation can be influenced by wind direction or building orientation. *Screenshot from Flow Design.*

Overall, the simulation of the ground floor of Quarters M shows that air movement through natural ventilation is able to move through the majority of spaces with the exception of the entry foyer. This is likely amplified by the wide open bays along the porch and garage openings which allow greater amounts of air to enter the interior compared to windows. Air flow through the building would increase if the prevailing winds shift to directly hit one of the building's facades, as indicated through an analysis using flow lines where the prevailing winds hit the main façade of the building and flowed throughout the interior.

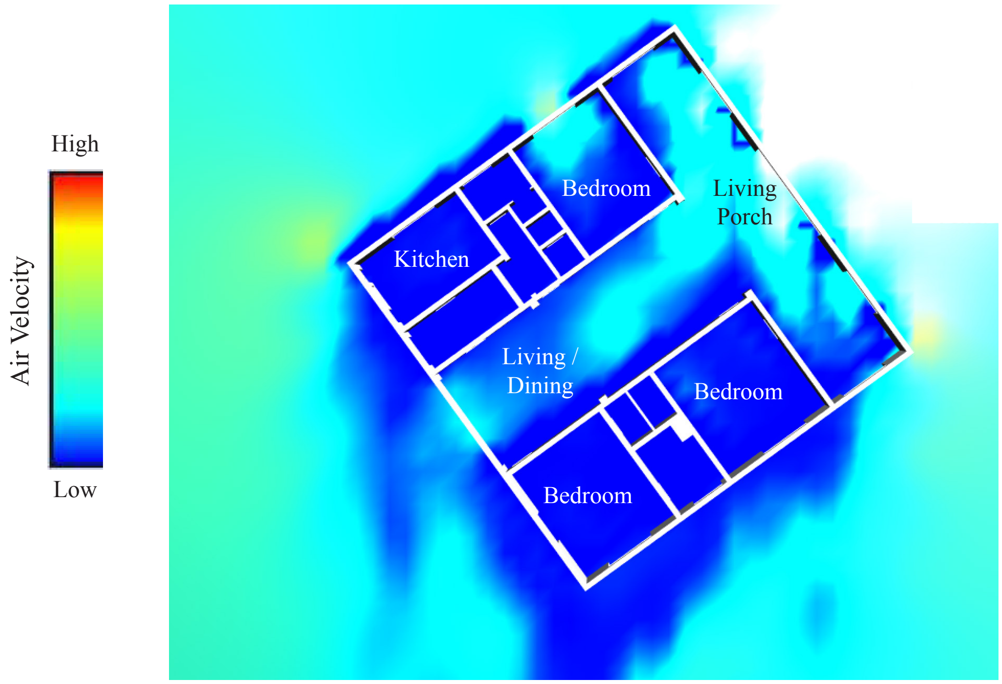

Figure 36: *Plan view of Quarters M, second floor - Flow Design simulation using shades.* This image shows the flow of air through the second floor; note the amount of ventilation through the central T-shaped portion of the plan. *Screenshot from Flow Design.*

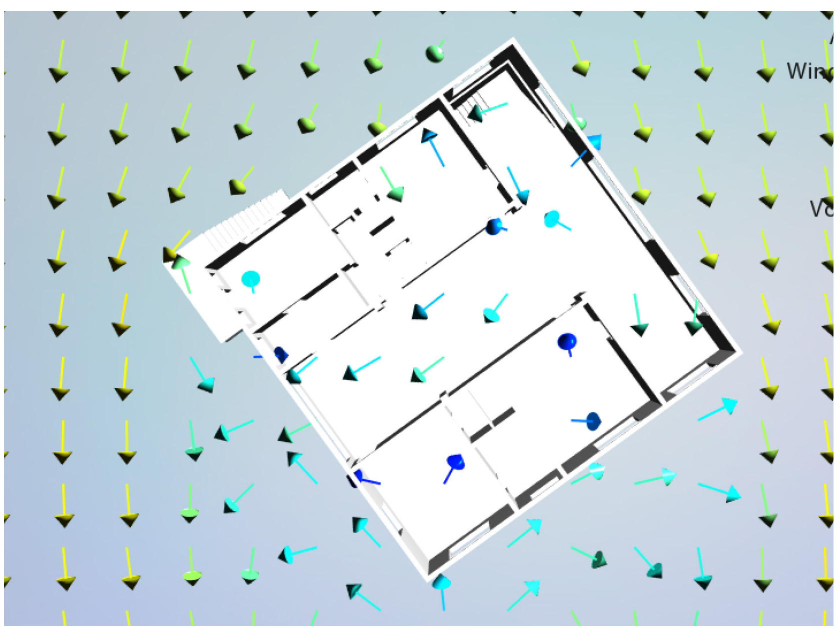

Figure 37: *Plan view of Quarters M, second floor - Flow Design simulation using vectors.* Viewing the simulation using vectors shows movement of air through the bedrooms and kitchen, which the shades visualization does not depict as well. *Screenshot from Flow Design.*

Simulations conducted on the second floor of Quarters M show that the spatial layout circulates air much more effectively than the ground floor. Prevailing winds hit the northeast corner of the building at the second floor level in the same manner in which they hit the ground floor. The large expanses of casement windows along the living porch on the second floor (the living porch comprises the top portion of the T-shaped central plan), allow large volumes of air into the interior. Directly above the ground floor porch, the living porch brings the air into the interior through the casement windows, down through the central living space and out through the large bay of casement windows in the west façade at the opposite end of the living space. Simulation of the entire house provides additional evidence for movement through the building, as vertical planes and flow lines show how air moves horizontally through the building's center. Cross-ventilation through the main space provides an increase in comfort by removing warm, still air and replacing it with cooler air.

Aside from the temperature difference, the simple movement of air around building occupants provides a greater degree of cooling. Opening doors and windows of the rooms on either side of the central living space further increases the effectiveness of ventilation as indicated by Figure 37 from the simulation where vectors are used to simulate air movement. This allows cross ventilation through the bedrooms in addition to the central space as air comes into the living porch and through the doorways of the two bedrooms adjacent to the space. Opening the casement windows at an angle where they are able to more effectively capture the direction of the breezes can also improve ventilation on the interior.

By utilizing natural ventilation as a form of passive cooling, the simulations show that the initial Panama House design affords a level of comfort relative to outside conditions during summer months.

Panama House Type II – Quarters T

Quarters T is one of two Panama Houses constructed in 1941 that follow a slightly different design from that used for the first eight Panama Houses constructed in 1937 and 1938. Both quarters of the later design are located on the western side of the Officers' Quarters Historic District close to the end of Hobson Avenue. The north (front) façade is oriented approximately 10 to 20 degrees (between north by east and north-northeast). This orientation is ideal for capturing the average prevailing winds, as the wind directly hits the main façade causing high wind pressure along the front of the building and low pressure at the back.

As one of the quarters that follows the design of the second version of the Panama House, the ground floor of Quarters T differs from that of Quarters M. The ground floor of Quarters M features a porch and foyer while the remaining spaces are largely secondary, serving supplementary functions to the rest of the house. Quarters T, however, has a modified ground floor that incorporates primary living spaces which include the

Figure 38: *Quarters T, Charleston Navy Yard.* Perspective photograph showing the front (north) and side (east) facades of the building. *Image by author.*

dining room and kitchen. Additionally, the porch along the front of the building has been truncated to only two bays rather than three, flanked to the west by a wall for the interior stair, and to the east by the servant's quarters. This shift in spatial organization means that ventilation of the ground floor of Quarters T is of greater importance than Quarters M due to the fact that primary living spaces on the ground floor mean that the primary occupants are intended to spend more of their time there.

The Flow Design simulation for Quarters T shows that the wind hits the front façade directly. On the ground floor, this causes wind to enter through the window in the north wall of the servant's room before exiting through the window in the east wall; this creates a cross-wind that circulates air through the room. Wind also travels through the two large porch bays before it enters the foyer by way of the main entrance and adjacent window.

Additional air is funneled from the porch into the den through a large window east of the foyer entry. From these points, air circulates through the rest of the ground floor, creating a strong cross-breeze that runs from the foyer through the dining room before exiting through a window along the rear façade. Some of the air from this cross-breeze circulates through the kitchen at lower velocities before exiting through the garage. Air is also able to enter the ground floor through windows along the sides of the building, although the amount of air coming into the interior in these areas is limited because the wind direction is parallel with the building facades which. This means that there is far less high wind pressure along the side facades to force air through the openings.

When running the simulation on the ground floor of Quarters M with the prevailing winds set to hit the front façade directly, the results are similar to those for the ground floor of Quarters T, with high levels of air circulation throughout much of the interior (see Figure 35 on page 127). This shows the level of influence that orientation can have on a building's ability to take advantage of wind currents for ventilation. It is important to note that the high level of air flow through the ground floor of the building does not necessarily mean that the later Panama House design is more effective at circulating air through natural ventilation.

The second floor of Quarters T largely follows the design of the original Panama House with the primary difference being the replacement of the kitchen with a fourth bedroom. Additionally, the two bedrooms closest to the north façade which are bordered

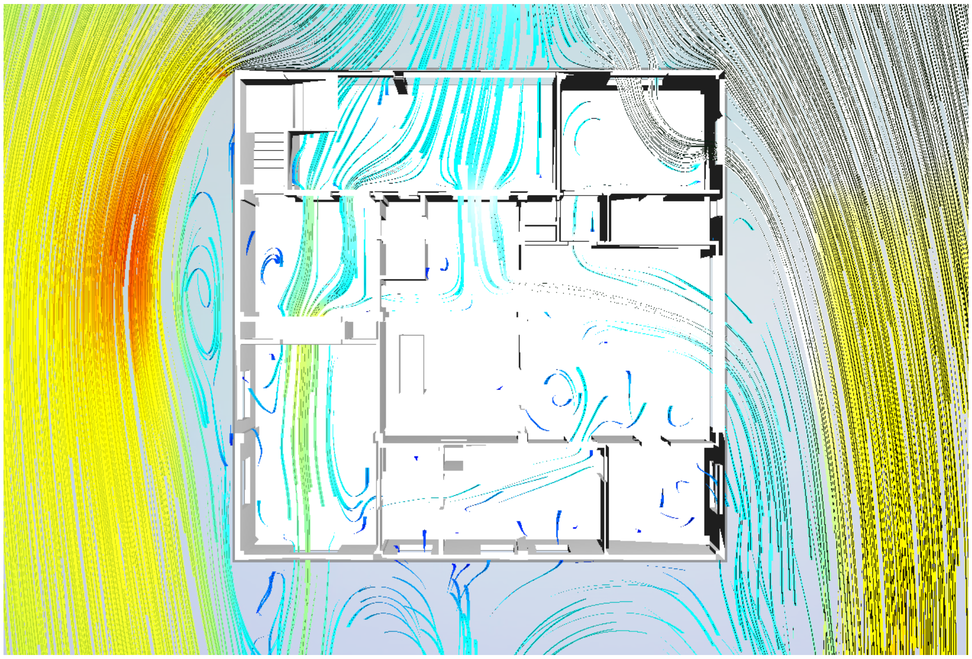

Figure 39: *Plan view of Quarters T, ground floor - Flow Design simulation using flow lines.* This image shows how natural ventilation allows air to flow throughout the ground floor in order to provide cooling and increase thermal comfort for the building occupants. *Screenshot from Flow Design.*

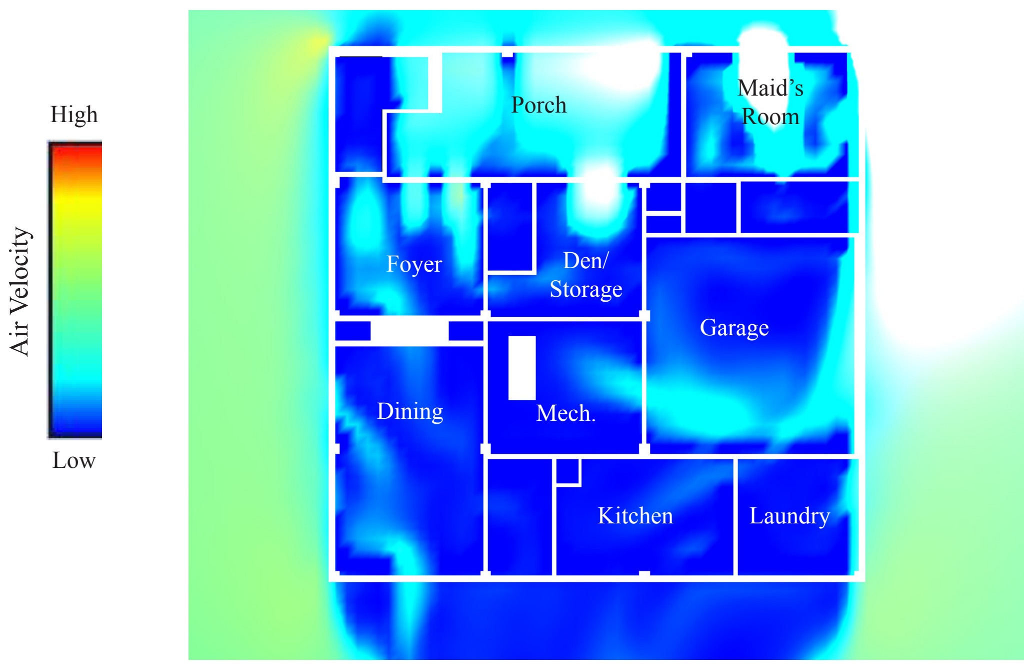

Figure 40: *Plan view of Quarters T, ground floor - Flow Design simulation using shades.* This image displays the same data depicted in the image above using a different method. *Screenshot from Flow Design.*

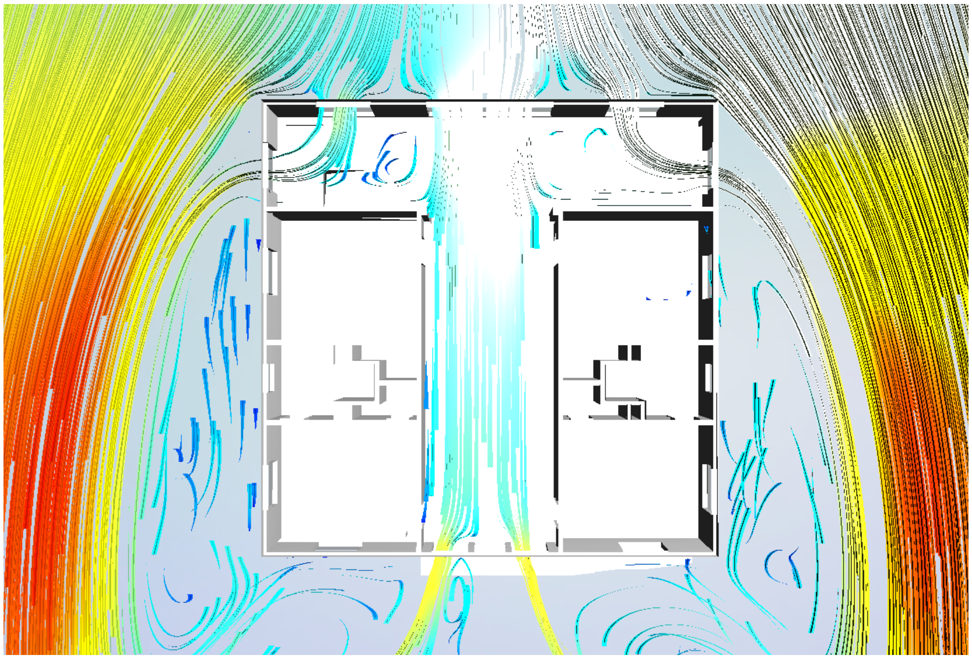

Figure 41: *Plan view of Quarters T, second floor - Flow Design simulation using flow lines.* Note the strong cross ventilation through the center of the second floor as it enters and exits through the two main bays at the front and rear. Additional cross ventilation along the living porch at the corners. *Screenshot from Flow Design.*

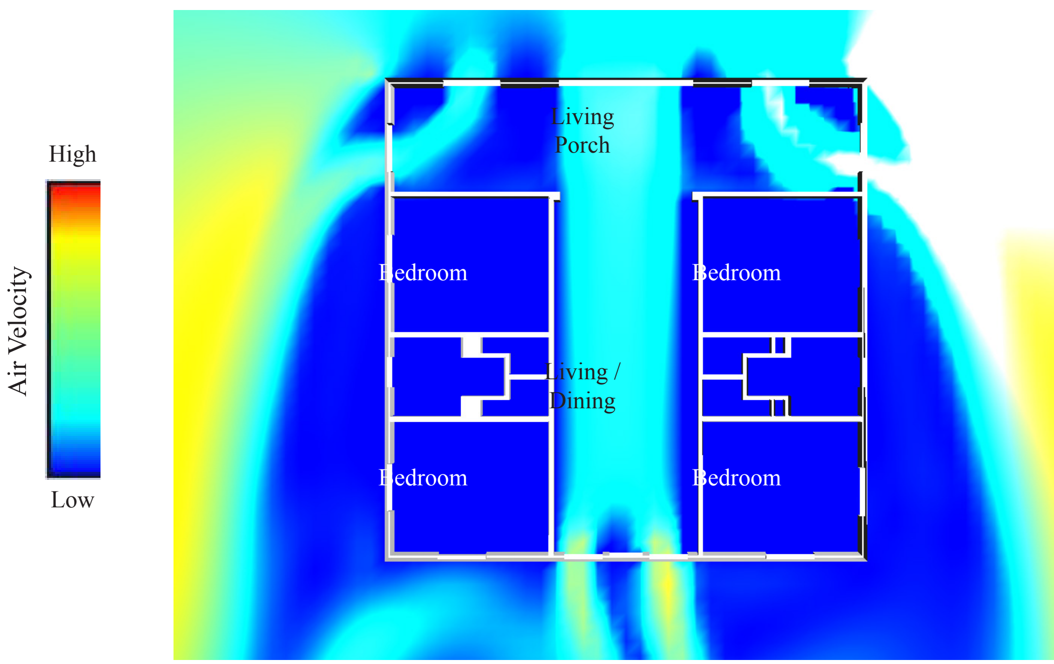

Figure 42: *Plan view of Quarters T, second floor - Flow Design simulation using shades.* This image displays the same data depicted in the image above using a different method. *Screenshot from Flow Design.*

by both the living area and the living porch only have one entrance rather than two as the original design had. Both bedrooms in this design only open onto the living area in the center of the room, meaning air cannot enter the rooms directly from the living porch.

The second floor simulation shows that air enters through the three windows along the front façade. The majority of the air that enters the two outside windows along the front is almost immediately forced back out of the building through the two windows along the side walls of the living porch. From the middle bay, however, cross-ventilation allows the majority of the wind to flow down through the central living area of the building and out the rear through the back entrance and flanking windows. The lack of doors in the north walls of the bedrooms closest to the living porch vastly decreases the amount of air flow into those spaces. Additionally, this further decreases the amount of ventilation moving from the front bedrooms to the rear bedrooms through the connecting bathrooms, central space in a way that the later design does not. This indicates that the initial Panama Houses is slightly better suited to the regional climate than the later Panama Houses, as the design exhibits greater efficacy in utilizing exterior air flow for passive cooling.

Quarters X – Control Building

Located at the western end of the Officer's Quarters Historic District, Quarters X was constructed as family housing in 1941, the same year that the last two Panama Houses were constructed. The building has a two-story main block with a one story extension at

Figure 43: *Quarters X, Charleston Navy Yard.* Perspective photograph showing the front (south) and right side (east) facades of the building. *Image by author.*

the rear. Rectangular in the plan, the main block of the house has a central stair hall on the first floor, flanked on the west by a living room and kitchen, and to the east by a dining room. On the second floor, two bedrooms are located on the east side of the house while the master bedroom and two bathrooms are on the west side. The center stair serves as the divider.

Smaller in size than the Panama Houses, Quarters X has several similar characteristics which include a hipped roof with triangular eyebrow vents. Quarters X was chosen as a control building due to its construction date which falls within the same years during which the Panama Houses were built.

The primary façade of Quarters X is oriented south by east at approximately 170 degrees. Due to its orientation, the average prevailing winds come in at a slight angle to hit the rear of the building rather than the front. The simulation of the model in Flow Design shows that despite the angle of the incoming winds, the first floor is able to ventilate relatively well. The majority of the air comes in through a north window in the north wall of the dining room as indicated by Figures 44 and 45. This creates a cross-breeze as the air moves through the dining room and out the window on the opposite side of the at the front of the house. Additional air comes into the dining room through the two windows in the east wall; as air runs parallel to the exterior wall, lower pressure on the interior pulls air into the room as it passes the window. Some of the air that comes into the dining room moves into other interior spaces before exiting the building as it moves through the entryway from the dining room into the stair hall. Some of this air escapes through the main entrance of the building while some continues through the stair hall and into the living room. This air current then encounters additional currents coming into the building through windows along the east façade in the kitchen and living room (see Figure 44). It circulates throughout these interior spaces, providing fresh air and cooling breezes before exiting through the south window in the living room, located along the front of the house.

This simulation shows that the first floor of Quarters X is well suited for natural ventilation, with air currents coming into all three of the primary living spaces on the floor. Movement of air through the interior removes standing or stagnant air, and can

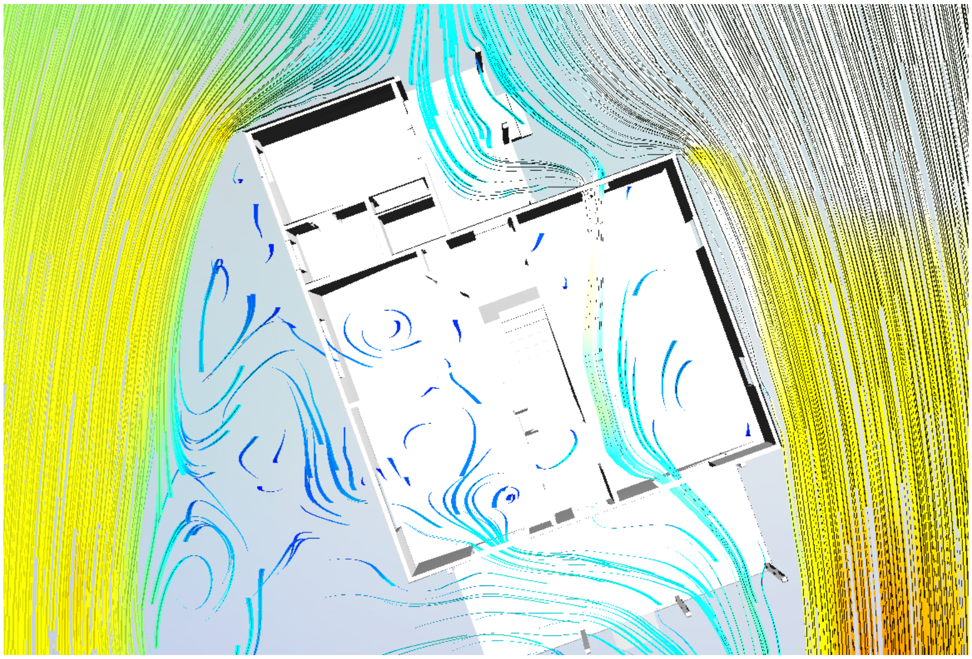

Figure 44: Plan view of Quarters X, ground floor - Flow Design simulation using flow lines. Note the level of cross ventilation through the dining room on the right side of the building. The kitchen and living room on the left receive much less ventilation with air moving at lower velocities. *Screenshot from Flow Design.*

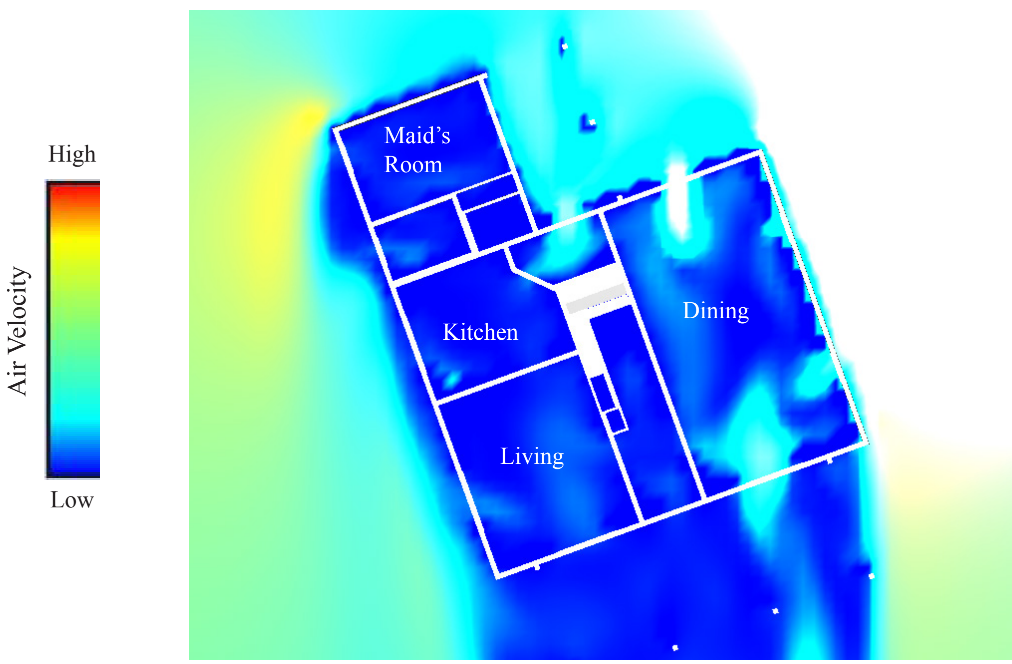

Figure 45: Plan view of Quarters X, ground floor - Flow Design simulation using shades. This image displays the same data depicted in the image above using a different method. *Screenshot from Flow Design.*

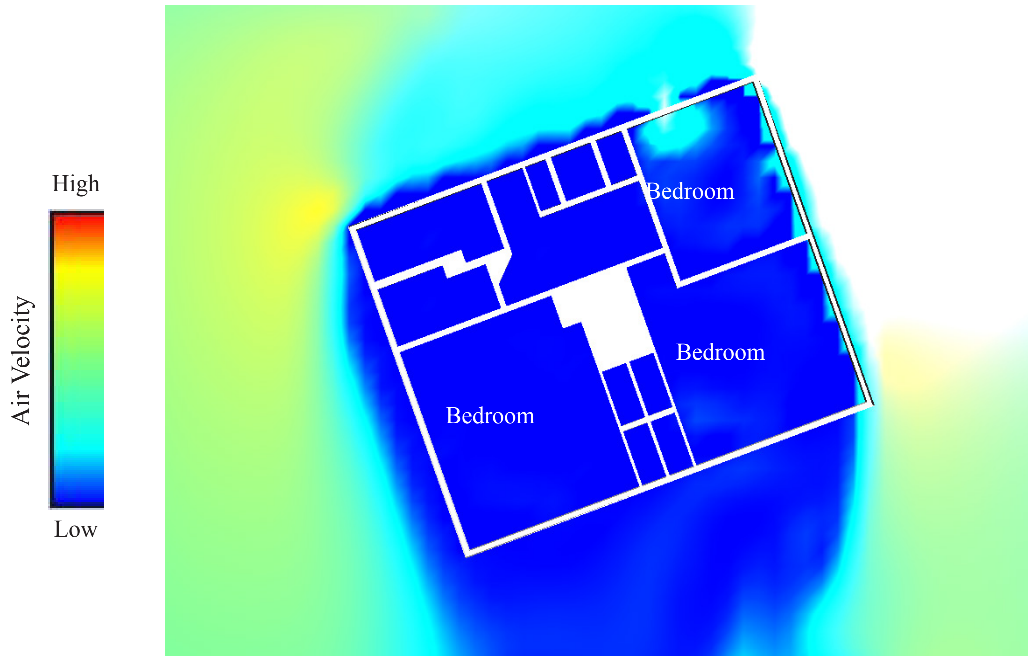

Figure 46: *Plan view of Quarters X, second floor - Flow Design simulation using shades.* The second floor receives much less ventilation than the ground floor. Note that while using shades to analyze airflow, only the northeast bedroom shows signs of air movement. *Screenshot from Flow Design.*

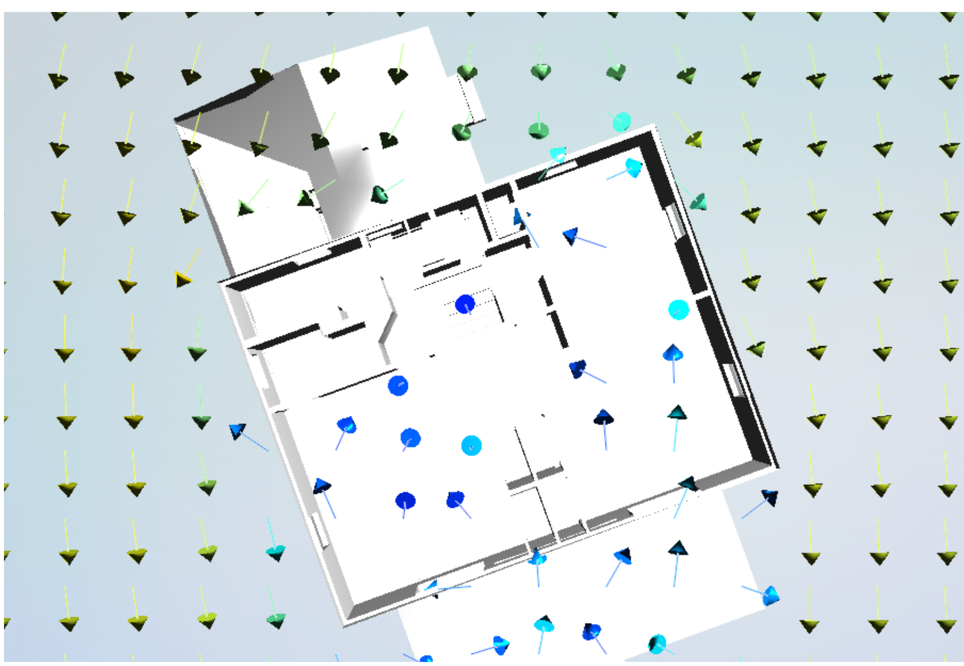

Figure 47: *Plan view of Quarters X, second floor - Flow Design simulation using vectors.* Using vectors reveals that there is movement in all three bedrooms, though at very low velocities. The limited air movement explains why it does not appear when viewing the simulation using shades. *Screenshot from Flow Design.*

be particularly useful for removing fumes from the kitchen or keeping occupants cool while dining. These results are similar to those from the simulation of the ground floor for Quarters T where air was able to move through the living spaces, providing adequate means of passive cooling.

Simulation of air flow using natural ventilation on the second floor of Quarters X yielded contrasting results when compared with the first floor simulation. Unlike the first floor, the second floor has fewer large window openings which restricts the amount of outside air allowed inside. Additional partition walls constrict the spatial layout of the floor by creating multiple smaller spaces and closing rooms off from one another. This removes openness from the plan as each room is only accessible from the center hall surrounding the stairs, further limiting the ability of the second floor to naturally ventilate.

During the simulation of the second floor, the results remained relatively constant. Like the first floor, the winds hit the rear of the house at an angle, reaching the northeast corner firsts. Shaded planes used to visualize air movement throughout the second floor space show that very limited amounts of air are allowed inside. The smaller bedroom at the northeast corner of the floor shows indications that small amounts of air are entering and exiting the room by way of single-side ventilation through the window in the north wall (rear façade of the house). At the front of the house, where the leeward side of the wind creates lower pressure, lighter shades of blue in the image indicate that small amounts of air are entering the two large windows which provide the two remaining bedrooms with limited air flow.

Using vectors to visualize air flow, arrows verify that there is air movement within the three bedrooms, but the color indicates that movement is at a relatively low velocity. Additionally, arrow directions signify that the air likely circulates through each room before exiting out the window through which it entered. This is also indicated by running the simulation using flow lines, which show slow air movement in the master bedroom that enters the window in the south wall before circulating the room and exiting back through the window. This means that single-side ventilation is the primary means of natural ventilation that provides external air flow into the interior spaces on the second floor.

The lack of adequate airflow on the second floor as indicated by the simulation means that the design of Quarters X does not thoroughly take climatic factors into consideration. Despite the fact that the first floor provides sufficient air flow, the building as a whole does not sufficiently ventilate. On the second floor this can negatively influence comfort level for the occupants since it houses the only spaces in the building that are designated for sleeping, an activity that depends largely on comfort. Additional, or larger, windows could help improve the level of airflow on the second floor, particularly if casement windows were used rather than double-hung sash windows that are currently in place. Without an open floor plan, however, changes such as these still will likely not provide equally efficient natural ventilation for Quarters X in comparison to the Panama Houses.

Quarters Y – Control Building

Quarters Y is located directly across Hobson Avenue from several of the Panama Houses in the western reaches of the district. Two stories in heights, Quarters Y is rectangular in plan and built using wood frame construction. The first floor has a central stair hall with a living room to the east and a study to the west. Both the dining room and kitchen are located at the rear of the ground floor. Attached to the first floor but not connected on the interior are the maid's quarters and garage. On the second floor, the stair hall is located at the center of the plan. Two bathrooms are located on this floor, one along the front façade and another along the back. Four bedrooms organized in pairs are located at each corner on the second floor. Each pair shares a bathroom. The design is primarily Colonial Revival. Like the Panama Houses, it has a hipped roof, although this is the only clear similarity between the two designs.

At approximately thirty by forty feet, the building is slightly smaller than the Panama Houses. Quarters Y serves as a control building due to its contrasting form and design, as well as its construction date of 1943 which falls fairly close to the years when the Panama Houses were constructed.

The main façade of Quarters Y is oriented facing southwest between approximately 220 and 230 degrees. This positions the building with the rear façade nearly in line with the average prevailing winds which hit the back of the building at a slight angle. Wind creates high pressure against the rear of the building which forces air through large window

Figure 48: *Quarters Y, Charleston Navy Yard.* Perspective photograph showing the front (south) and right side (east) facades of the building. *Image by author.*

openings in the dining and living rooms. Air entering into the dining room crosses into the large living room through an entry way in its east wall that connects the two rooms. The air currents then hit additional air entering the living room through a window in the north wall at the rear of the house, combining to create a larger mass of air flow to circulate through the room. Some of the moving air exits through the two windows in the east wall while the majority leaves through the large window in the south wall at the front of the house. Smaller air currents travel into the stair hall before going out either the main entrance or across the hall into the study before exiting through the single window centered in the south wall.

These Flow Design simulation results show that only portions of the first floor

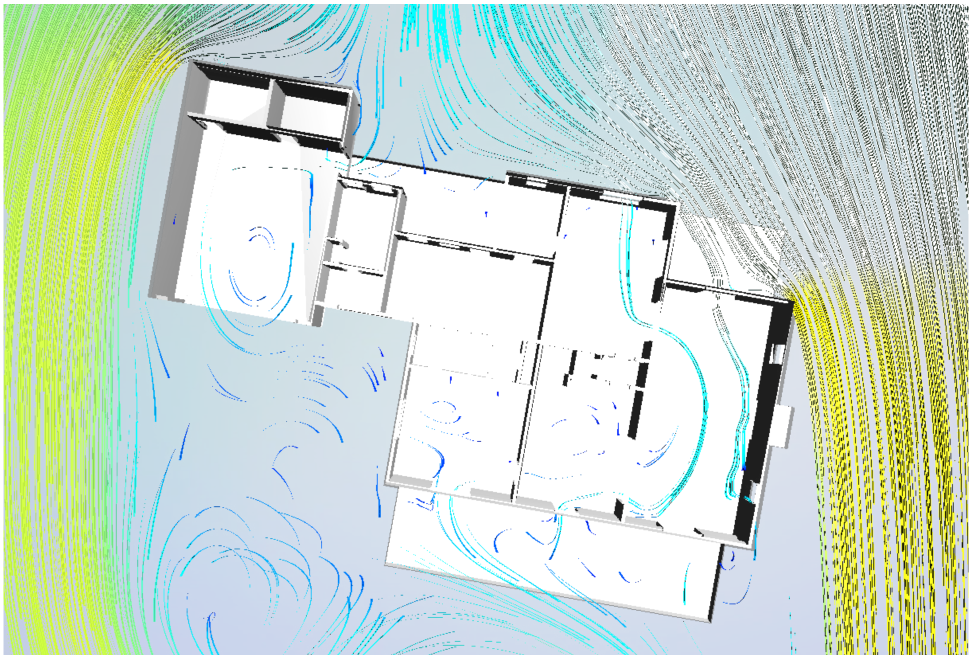

Figure 49: *Plan view of Quarters Y, ground floor - Flow Design simulation using flow lines.* Note the air coming into the dining room at the rear and cross-ventilating into the living room. The simulation showed that both rooms are well ventilated. The stair hall and study along the front, however, receive far less airflow. *Screenshot from Flow Design.*

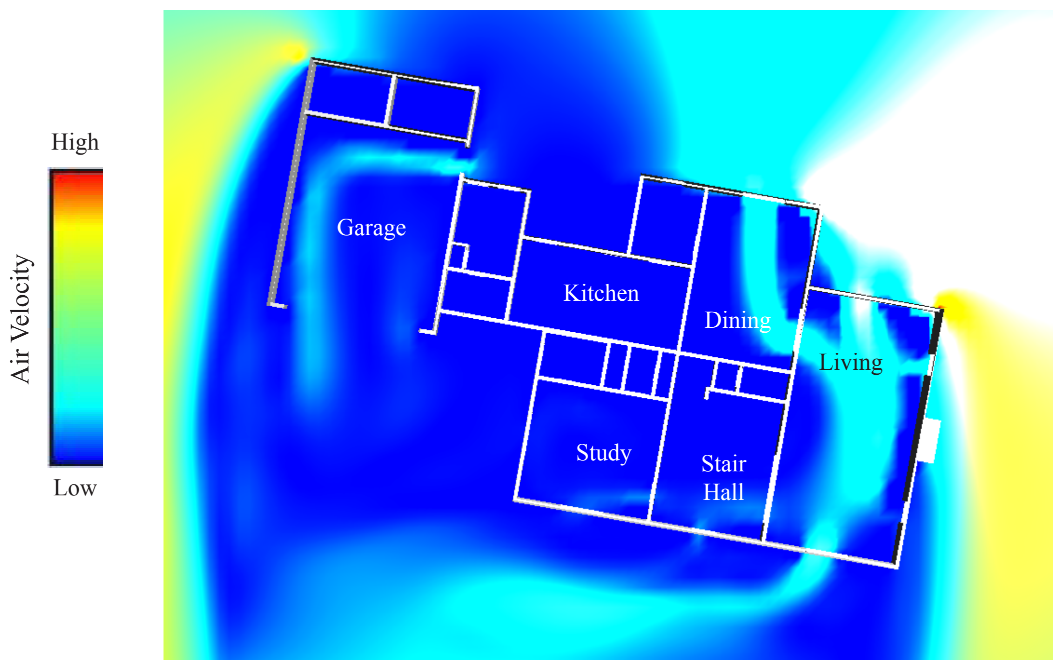

Figure 50: *Plan view of Quarters Y, ground floor - Flow Design simulation using shades.* This image displays the same data depicted in the image above using a different method. Note the iar moving through the dining room at the rear and the living room on the right edge. *Screenshot from Flow Design.*

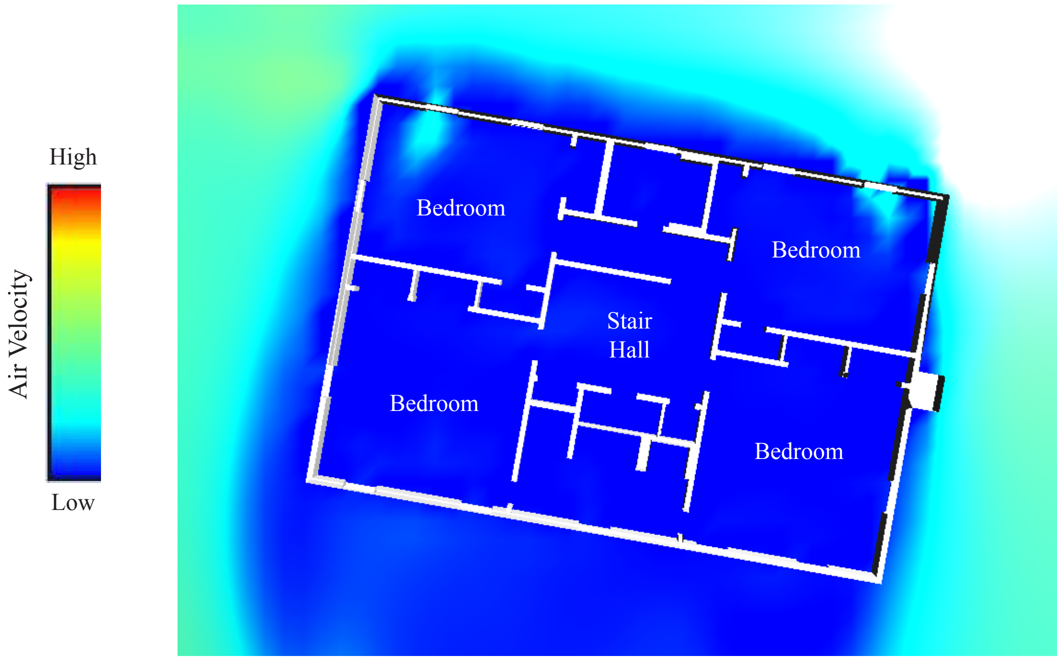

Figure 51: *Plan view of Quarters Y, second floor - Flow Design simulation using shades.* The second floor receives much less ventilation than the ground floor. Partition walls separating rooms from one another restrict air. Note how air appears to only enter into the two rear bedrooms. *Screenshot from Flow Design.*

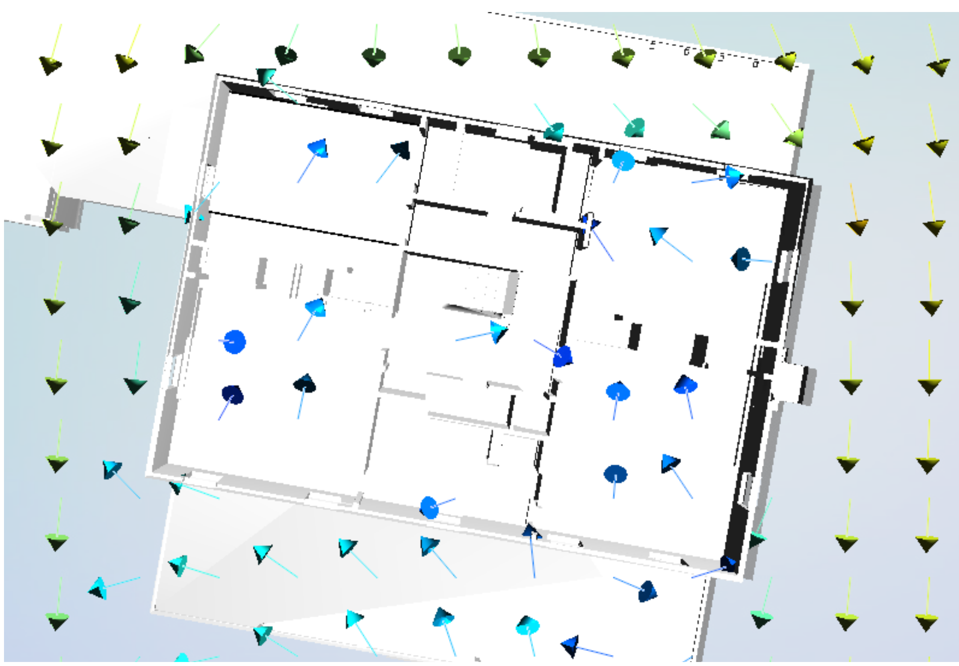

Figure 52: *Plan view of Quarters Y, second floor - Flow Design simulation using vectors.* Using vectors reveals that there is movement in all four bedrooms, though at very low velocities in each room. These results reveial that the second floor is much less suited for natural ventilation. *Screenshot from Flow Design.*

receive favorable levels of air flow from the prevailing winds. Although there are partially open elements to the floor plan, partition walls limit air movement to other spaces throughout the first floor, primarily between the stair hall and study at the front of the house with the rooms at the rear. The simulation makes it clear that the dining room and living room are the only two spaces that carry relatively high air velocities from natural ventilation. This is likely because they are the only two rooms that have effective window placement to allow large amounts of external air into the interior. The stair hall and study at the front of the house see far less air movement which is due to the fact that the air circulating through both spaces is secondary, with most of it having been pulled off from the main course of air currents traveling through the living room at the east end of the building. Minimal air movement in these two spaces likely does little to alleviate thermal discomfort compared to the dining and living rooms.

What is interesting is that when observing the simulation using shades, vectors, and flow lines, the model shows no air movement within the kitchen. This can be partially attributed to a decrease in air velocity when wind hits the small rear porch that borders the kitchen. Interior spaces nearly enclose the kitchen on the three remaining sides. This restricts the outside flow of air to the point that doorways into adjacent spaces serve as the primary outlets for air circulation into and out of the kitchen. It is likely due to these reasons that the simulation showed no air movement in the space.

When analyzing the ventilation capabilities of the second floor of Quarters Y, the results are similar to those for the second floor of Quarters X. The organization of space is comparable with partition walls separating rooms from one another. Each room opens onto the central stair hall; the only exception to this is the bathroom along the front of the house that connects two of the bed rooms – the second bathroom is accessed from the hall. This inhibits the ability of the second floor spaces to ventilate as a single system in the manner that an open or partially open floor plan would be able to. Instead, the simulation indicates that the rooms generally ventilate on an individual basis.

The majority of wind hitting the rear of the house is diverted around the building mass, with limited amounts of air being forced into the two bedrooms along the back of the building as indicated by Figure 50 which depicts air movement using shades. Although flow lines show no air movement on the second floor, vectors indicate in the simulation that air circulation does occur in each bedroom but to a limited degree. The shade of the vector arrows indicates that the air is moving at a very low velocity, which explains why it appears as if no air movement is going on when viewing the simulation using shades. The simulation demonstrates that the air circulation on the second floor appears to occur through single-side ventilation occurring in each room, with low levels of cross ventilation taking place between the front two bedrooms as indicated by the vectors.

Like Quarters X, the absence of high levels of air movement and circulation throughout the interior spaces on the second floor of Quarters Y hinders the building's ability to utilize natural ventilation. This creates the potential for stifling air to build in interior spaces, which leads to high, uncomfortable temperatures due to lack of necessary air flow to alleviate thermal discomfort.

Comparison of Simulation Results

The simulations conducted for this analysis produced varying results for each building. Some of these outcomes were expected, such as the ability of the central T-shaped portion of the second floor plan of the Panama Houses to utilize cross-ventilation. This pulls cooler air into the interior to allow an increase in the level of thermal comfort for occupants. Despite this similarity, air flow varied for the smaller rooms that surrounded the living area on the main floor of the Panama Houses. Changes in the design as seen in the later version of the Panama House differed from the initial 1937 plan; these changes resulted in a reduction in the building's ability to ventilate the rooms along the sides of the second floor. This was indicated in the simulations which show wind velocity through side rooms on the second floor of the initial Panama House design at up to approximately 20 ft/s (6.09 m/s), while the simulations for the later design showed little to now movement at all. Based on the psychrometric chart for summer months (Figure 53) which shows how natural ventilation can increase the allowable comfort zone within a building, the velocity of air circulating through the rooms flanking the central space in the initial Panama House design would efficiently improve interior comfort, potentially increasing the temperature (DBT) at which thermal comfort can be achieved by more than 10 degrees Fahrenheit.

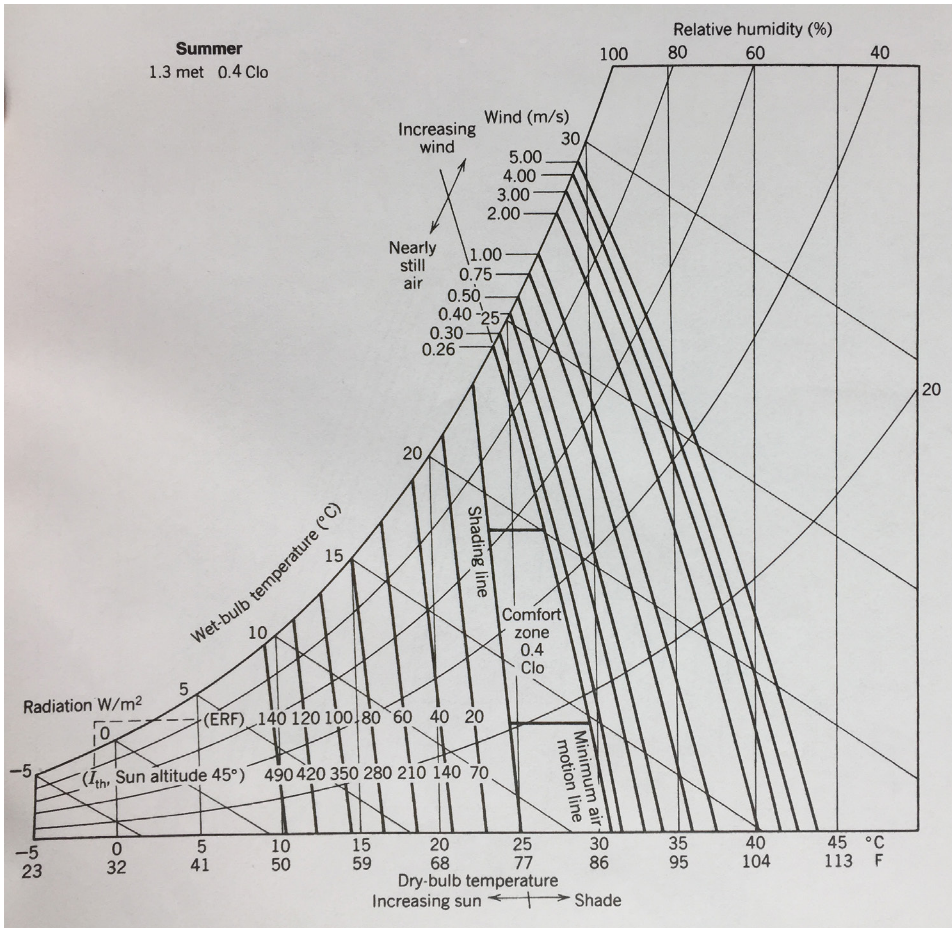

Figure 53: *Psychrometric Chart - Summer.* This chart shows the how natural ventilation can increase comfort. Note how increasing the velocity of wind correlates with an increase in comfort. Levels of shade and humidity also play a role in comfort levels. Benjamin Stein and John S. Reynolds, *Mechanical and Electrical Equipment for Buildings*, (New York, NY: John Wiley & Sons, Inc., 2000), 50.

This reinforces the conclusion that the original Panama House design was more effective than the later iteration from 1941.[156]

In contrast, the designs of the control buildings are less adequately suited to the climate. Evidence from the Flow Design simulations shows that while the control

156 Please see Appendix E for full screen-shots from the Flow Design simulations which show the air velocity key and corresponding speeds in feet per second. These speeds are approximate and are based on the parameters applied to the model. Context of other land features at the Navy Yard that could decrease wind velocity were not taken into account for buildings located away from riverfront.

buildings provide sufficient natural ventilation for various interior spaces on the ground floor, ventilation levels are severely restricted when the simulation is applied to the rooms on the second floor. This is due in part to the differences in the design and spatial organization between floors. Whereas the first floors of the buildings feature areas that are open in plan, the second floors do not. Partition walls close the rooms off from one another and smaller sash windows are less capable of letting in outside air, which limits the alleviation of discomfort. The simulations for Quarters X indicated that the maximum wind velocity in rooms on the first floor are approximately 25 ft/s (7.62 m/s), primarily in the dining room. Conversely, the simulation for the second floor showed that only the northeast room receives any level of air flow that might provide some alleviation to thermal discomfort. Quarters Y produced similar results, with maximum wind velocity on the first floor reaching approximately 30 ft/s (9.14 m/s), which would greatly increase comfort levels in rooms where it applies. These levels of wind velocity were primarily in the dining and living rooms; significantly less air movement occurred in the stair hall and study. Again, like Quarters X, air movement on the second floor of Quarters Y was nearly still according to the simulations. Such results are undesirable for building occupants, and show the deficiency in the plans of the control buildings to utilize natural ventilation to passively cool second-floor spaces.

Natural ventilation is of notable importance on these floors since they house the only bedrooms for each building. Although thermal comfort is relevant for all interior spaces, it is especially so for bedrooms where thermal discomfort can prevent building occupants from falling asleep and staying asleep. The lack of climatic adaptive elements in the control buildings indicates that climate was not likely a leading factor in their design or construction. Although both examples have hipped roofs with vents, little else is incorporated into the design to alleviate possible problems associated with the climate. Small eaves, double-hung windows, and traditional floor plans with multiple partition walls play a role in minimizing the natural ventilation ability of the buildings.

Simulation results show that the Panama House designs have greater potential for natural ventilation as a means of passive cooling. In this manner, the Panama House designs afford a higher level of comfort relative to the other buildings by effectively utilizing passive cooling methods to increase thermal comfort on both floors. The climatic adaptive features incorporated into the Panama House designs play the primary role in minimizing direct solar gain and allowing increased air circulation to provide natural ventilation than other building types at the Navy Yard. Design features such as the partially open ground floor, casement windows, open floor plan, and low-pitched hip roof with overhanging eaves are just some of the important and character defining features of the Panama House design that provide air circulation and heat reduction.[157] All of these architectural elements are

[157] Outward-swinging casement windows are important features in the Panama House design because they can be opened at various angles which allows them to effectively capture breezes. This is particularly useful when wind is moving in a direction that does not directly hit a building facade, which reduces the amount of airflow into the interior. In such scenarios, casement windows can be angled to catch the wind and bring additional air inside. This improves the building's ability to ventilate through passive cooling methods and alleviate thermal discomfort despite the direction that the wind is traveling.

essential to the Panama House design, working in conjunction with one another through passive methods in a sustainable manner. Together, the climatic adaptive features of the Panama House contribute to make it an efficient vernacular design that is well-suited for the Charleston climate. These same adaptive elements are what made the design work so well in the Panama Canal Zone. From the results of this analysis, evidence indicates that the regional suitability of the Canal Zone architectural type led to the importation of its design in Charleston.

CHAPTER EIGHT:

CONCLUSION

In Chapters Six and Seven, the Panama Houses were analyzed using two different methods that explored the origins of the building type at the Charleston Navy Yard and how its plans and architectural features allow the designs to exploit the climate through passive methods. Using architectural comparisons and airflow simulations, the purpose was to place the Panama House designs within their foreign context while simultaneously establishing their suitability as climatic adaptive designs suited for the Charleston region.

Prior to the research conducted in this study, it was understood that the Panama Houses were adapted from plans for housing in the Canal Zone designed by the Army Quartermaster. Through the comparison between the Panama Houses and architectural designs for housing in the Panama Canal Zone, distinct characteristics and features emerge to set a pattern that can be drawn between the two types. During the construction of the canal and its subsequent militarization during U.S. control and operation, the climate of the isthmian region played a strong role in the development of the form of architecture that became the standard vernacular type so recognizable in the Canal Zone. This is evident from various sources, including design guidelines for architecture in the region that were created in the first decade of the twentieth century. The guidelines state that climate must be taken into account in order to create a building type well suited for the locale. Coupled with this statement are the architectural features and the designs themselves. Early housing types had concrete footings used to support wood post foundations that required little if any excavation and protected the rest of the structure from rotting. Use of concrete eventually developed from footings to full-fledged reinforced concrete structures. Wood frame shifted from being used as the primary construction material in earlier buildings to being reserved in later concrete structures for roof framing and openings. Features such as large porches and verandas, wide overhanging eaves and mediagaus provided dual roles by protecting the building from direct solar radiation as well as heavy rains. Various other design elements including screens, vents, grates, louvers and jalousies provided natural ventilation to circulate air and alleviate discomfort in the hot-humid Panamanian climate. These factors and elements that shaped the Canal Zone architecture are what made it distinct enough to be its own vernacular type.

This building technology was first used in French colonial housing during their efforts to construct a canal, and continued to develop under the auspices of the United States, implementing climatic adaptive features into building designs that eventually developed into the Canal Zone vernacular form. The reason that these building elements did not fade from use is because they worked, so they continued to be applied and developed over the course of many decades because they were proven to be efficient over alternative forms and elements that may have been considered. Clearly, based off the research and simulations conducted, regional climate played an extensive role in the successful design and construction of Canal Zone buildings.

The design and construction of the Charleston Navy Yard Panama Houses in the 1930s coincides with Canal Zone housing of the same decade. Architectural details, organization of plan, and spatial hierarchy of the Panama Houses follow the same standards of their Canal Zone counterparts, ultimately positioning the Panama Houses as a directly imported architectural form with limited alterations and adaptations from the original. As far as the research indicates, Charleston is the only place outside of the Panama Canal Zone that this building type was constructed. As a distinct importation of an architectural form, the Panama House designs were ultimately influenced and shaped by the Panamanian climate since they were adopted from the region. Chapter Six indicates that the plans for the buildings were seemingly left unchanged, at least in the initial Panama House design, as they appear identical to various Canal Zone types in terms of plan with the exception of size. This design was adapted for the last two Panama Houses constructed at the Navy Yard in 1941, making the building type an evolutionary form. However, with the abandonment of the Panama House design at the base after this date, and the lack of proliferation of the architectural form outside of the Canal Zone, construction of the final Panama Houses signified an evolutionary dead end for the building type at the Charleston Navy Yard.

Although testimony advocates that the design was tested and proven to work well with the climate in Panama, it remained to be seen whether it would be as capable in Charleston. The inclusion of a heating system in the CNY Panama Houses, along with a fireplace, ensured that they would meet the necessary heating requirements for the often temperate winters typical of Charleston. One of the underlying assumptions of this study was that the Panama Houses are adapted for the climate of the South Carolina lowcountry; this needed to be proven using data to assess the passive cooling techniques of the designs. Fortunately, the results of the Flow Desgin airflow analyses conducted for this purpose largely supported this case. Simulation results showed that the use of multiple window openings on all four facades, including large central bays along the front and rear of the buildings, provide suitable openings to allow outside air to access the interior. Together with the spatial layout of the second floor, levels of natural ventilation are amplified by allowing air currents to move through interior spaces by cross-ventilation. This brings cool air into one side of the house and forces warm air out another. Results from the Panama House simulations provide visual representations of the strong cross-breezes that move through the central T-shaped living area of the second floor. Air currents break off from the cross-breeze to circulate through flanking rooms. While the constant replacement of air already provides a degree of comfort, the physical flow of air supplies additional alleviation. Although not necessarily cooler in temperature than still air, flowing air gives off a similar cooling effect that makes occupants feel cooler, and thus, more comfortable. This is because interior air can be stale or stifling if it is not circulating.

Although not included in the simulation, additional heat is removed through the roofing system which has vents under the eaves along the side elevations. These allow cool outside air into the attic space which travels out the two louvered vents at the top of roof. By circulating air into the attic, vents reduce the build up of heated air which can impact thermal comfort levels on the floor below. This, in conjunction with the partially-open ground floor, provides natural ventilation to cool spaces above and below the main living space to reduce external thermal stresses.

A primary conclusion that can be drawn from these simulations is that the Panama Houses really do work as climatic adaptive buildings in the Charleston region. Their design allows for efficient ventilation through passive cooling methods, while elements such as wide eaves provide solar shading to reduce direct thermal gain. Competence of the design is proven further by the clear inadequacy of the control buildings to utilize natural ventilation when compared to the Panama Houses, as evident from the Flow Design analyses. Additionally, tying their designs back to original structures in the Canal Zone provides definitive context for the Panama Houses as a type, confirming that they are a derivative of the original isthmian architectural form.

A more important conclusion from the simulations and analysis, however, is that the data and results produced show that these kinds of tools are applicable to vernacular architecture studies rather than purely for use with new building and product design. Software programs such as Flow Design are an effective means to assess the ways that vernacular architecture types relate with their regional climate, particularly for historic building types believed to have been designed and constructed with climatic factors taken into consideration.[15858] By using this approach, it can be determined whether historic buildings were well-suited for the region in which they are constructed, or explain why building forms evolved over time. Such programs may prove to be increasingly important tools for vernacular studies in the near future as they can be applied to singular regional forms and types, and to entire urban landscapes to assess built environments.

Vernacular building types typically never cross into foreign regions or are adopted in other parts of the globe. In the limited cases where porting does occur, placement in a new locale, while likely representing a distinct architectural type there due to its unfamiliar form, does not make the design a vernacular form within the new region unless it is altered. Rather, the classification of a form as a vernacular type only remains applicable to its place of origin. By tracing the origins of the Panama Houses at the Charleston Navy Yard, it is clear that this case is one such example, as the specific form for the buildings was directly imported and adopted by the Navy Yard from Canal Zone housing. The symmetry and patterns between the two are clear, supporting the case that the Charleston Navy Yard Panama Houses are indeed a climatically adapted vernacular form imported from a foreign context.

[158] One example of an architectural form that this methodological approach can be applied to is center-passage houses. The center-passage in buildings that follow this design was sometimes referred to as the "breezeway", allegedly because opening the front and back doors to the house at each end of the center-passage would produce a breeze directly through the building that could then circulate through rooms located on each side of the passage, as would be expected through cross-ventilation. The effectiveness of this form to passively cool by using natural ventilation could be analyzed using Flow Design simulations, following the method that has been laid out in this study.

Components of Further Analysis

The components of further analysis largely consist of additional data collection within the context of the Charleston Navy Yard and in the wider frame of the Republic of Panama. To strengthen and provide additional information and details about Canal Zone housing, traveling to the region of Panama and investigating the various housing types first hand would prove to be invaluable to further research on the topic. Conducting further work in Panama would provide useful information on the development of housing in the Canal Zone from socio-cultural and economic perspectives as archives and repositories in the region have additional primary source material that would likely prove helpful in expanding the comparative analysis between U.S. housing in the Canal Zone and the CNY Panama Houses. From a narrower perspective, collection of additional data on the Panama Houses by conducting supplementary simulations for passive methods such as solar shading would be useful. Furthermore, analysis of building materials used in the construction of the Panama Houses could be helpful in gleaming additional data about the climatic adaptive features of the design. Although the buildings are already designed with climate taken into account, material properties can help determine which components used in construction of the buildings are best suited to the climate and whether they have any influence on the degree to which thermal comfort is achieved.

APPENDICES

Appendix A:

Additional Photgraphs of the Construction of the Panama Houses

The following photographs depict the construction of the first four Panama House - Quarters K, L, M, and N - at the Charleston Navy Yard. Dates on the photographs indicate that construction began as early as 1936. The first of the buildings was completed in 1937. Works Progress Administration signs indicate that the construction of the buildings area WPA project can be seen in several of the images. Images are arranged in chronological order. Some of these photographs were obtained from the Charleston Naval Complex Redevelopment Authority, others were provided by Don Campagna, History and Archives Coordinator for the City of North Charleston.

Figure A.1: *Carpenter Shop, 3 February 1937.* This photograph shows the carpenter shop, likely where the lumber used in the construction of the Panama Houses was stored. *Image courtesy of Don Campagna and the City of North Charleston Archives.*

Figure A.2: *Two New Quarters, 3 February 1937.* This photograph shows the construction of two of the Panama Houses, likely Quarters K and L. *Image courtesy of Don Campagna and the City of North Charleston Archives.*

Figure A.3: *Perspective View Looking SW, 22 March 1937*. Close to completion. Note the concrecte supports that make up the ground floor structure and the exposed hollow block that fills the ground floor bays. *Image courtesy of Don Campagna and the City of North Charleston Archives.*

Figure A.4: *Panama House, 22 March 1937.* The building in this picture is likely Quarters M or N since they were completed after K and L were finished. Note the materials: concrete, hollow tile, and wood frame. *Image courtesy of Don Campagna and the City of North Charleston Archives.*

Figure A.5: *Perspective View Looking NW, 22 March 1937. Image courtesy of Don Campagna and the City of North Charleston Archives.*

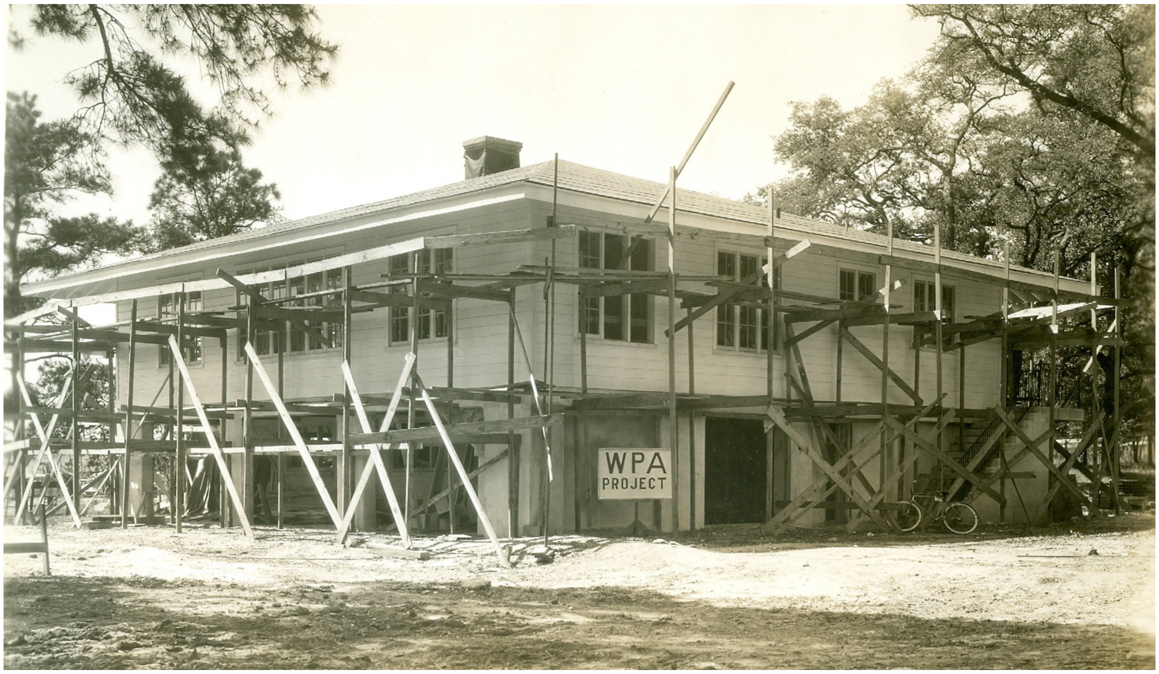

Figure A.6: *Panama House, Window Installation, 12 April 1937. Image courtesy of Don Campagna and the City of North Charleston Archives.*

Figure A.7: *Forms for Concrete, 03 August 1937. Image courtesy of the Charleston Naval Complex Redevelopment Authority.*

Figure A.8: *Completed Panama House, 03 August 1937*. Note the open windows to capture the breeze. *Image courtesy of the Charleston Naval Complex Redevlopment Authority.*

Figure A.9: *Perspective View Looking N, 18 November 1937. Image courtesy of Don Campagna and the City of North Charleston Archives.*

Figure A.10: *Panama House with Scaffolding, 18 November 1937. Image courtesy of Don Campagna and the City of North Charleston Archives.*

Figure A.11: *Panama House Construction, 25 March 1938*. In this photographs, the ridge vents and chimney have yet to be installed. *Image courtesy of Don Campagna and the City of North Charleston Archives*

Figure A.12: *View from Golf Course Looking E, 25 March 1938. Image courtesy of Don Campagna and the City of North Charleston Archives.*

Figure A.13: *New Shipbuilding Ways, 01 August 1938*. Note the Panama House in the Background; this building specifically is Quarters N. *Image courtesy of Don Campagna and the City of North Charleston Archives.*

Figure A.14: *View NW towards Quarters N, 13 September 1938. Image courtesy of Don Campagna and the City of North Charleston Archives.*

Figure A.15: *View NE along Quarters N, 13 September 1938. Image courtesy of Don Campagna and the City of North Charleston Archives*

Figure A.16: *Quarters S, Looking NW, 13 January 1941. Image courtesy of the Charleston Naval Complex Redevlopment Authority.*

Figure A.17: *Quarters T, Looking South, 03 March 1941. Image courtesy of the Charleston Naval Complex Redevlopment Authority.*

Figure A.18: *Excavation for Building, 01 November 1941.* Note the Panama House in the background. *Image courtesy of the Charleston Naval Complex Redevlopment Authority.*

Figure A.19: *Excavation for Building, Looking Northeast, 01 November 1941. Image courtesy of the Charleston Naval Complex Redevlopment Authority.*

Appendix B:

Index of United States Housing in the Panama Canal Zone

This appendix contains images of architectural drawings and photographs of known types of quarters at several former U.S. military installations and townsites located throughout the Panama Canal Zone. Acting primarily as a supplement to Chapter Six in which the designs of housing in the Canal Zone were compared with the design of the Panama Houses at the Charleston Navy Yard (CNY), this compilation serves as a visual aid for the various Canal Zone housing types. The following drawings and photographs were pulled from the Library of Congress in Washington, D.C. and the National Archives and Records Administration in College Park, Maryland. The matching repository location for each photograph or drawing in this section is provided to allow for further research or access to the source.

The contents of this section are organized alphabetically by military installation or town site location. Under the section for each installation, a brief history is provided followed by the corresponding quarters for the installation. These are broken down according to their intended use, whether serving as civilian housing or as quarters for Field Officers (FO), Non-Commissioned Officers (NCO), Commanding Officer (CO), or general quarters. Plans of housing types that have a type number but no written indication of what personnel they were to house are listed at the end of each section. Miscellaneous quarters types for which no installation or location was specified on the drawings can be found in the last section of this appendix.

The number of drawings and photographs for each building type are limited by what was available at the National Archives and Library of Congress. While some types have both photographs and drawings, the majority have either one or the other. Due to this factor, the design of some building types which are supplemented with photographs and drawings are typically laid out in much more detail than those for which limited materials were available.

Information provided includes location, use, date of the photograph or drawing when available, and notes on the design or plan of the building. The amount of information and level of detail provided for each quarters type varies depending on what was noted or documented with each photograph or drawing. Additional information provided for each type may include variations and similarities with other Canal Zone housing. For types where there are multiple versions of the same standard design, less information is provided for the subsequent designs in order to limit repetition.

Note: This appendix does not include every former U.S. military installation in the Panama Canal Zone, nor does it include every type of quarters for the installations that are listed. Rather, it is a culmination of materials that were available during research.

CONTENTS

ALBROOK AIR FORCE STATION

Albrook Air Force Station was a former United States Air Force installation located in the Panama Canal Zone on the east side of the Canal's Pacific entrance. It was constructed during the 1930s to bolster the capabilities of the military personnel stationed in the region to defend the Canal against air attack - a growing threat due to the development of aviation technology and the advent of Aircraft Carriers. After the United States turned over it's remaining military installations in the Canal Zone to the Republic of Panama in 1997, Albrook Air Force Station was redeveloped as Panama's International Airport, suitably located outside of Panama City.

Civilian Quarters

Location: Albrook AFS
Date of Photograph: 1937

Figure B.1: *Civilian Quarters, Albrook AFS, PCZ, 1937.* Also found on page 92, Figure 18. *Image courtesy of the National Archives and Records Administration.*

This photograph of a row of Civilian Quarters located at Albrook Air Force Station shows one of the earlier forms of housing in which the buildings is set on wooden posts with concrete footings. The concrete footings are meant to prevent water absorption through the footing, but also to keep termites from getting into the wood. These concrete footings usually had a copper or another kind of metal plate between the concrete and wood to serve as a separation. Chemicals were often applied to the copper sheet to further deter termites and other insects that might damage the wood. The use of wooden stilts indicates that this is an earlier form of housing, or possibly meant to be temporary housing. Permanent structures were typically constructed entirely of concrete on the ground floor.

This is the only identified photographs for this quarters type. It was obtained from the National Archives and Records Administration in College Park, Maryland. See References for further details.

Company Officers' Quarters

Location: Albrook AFS
Date of Photographs: 1990s

Figure B.2: *Company Officers' Quarters, Front Elevation, Albrook AFS, PCZ. Image courtesy of the Library of Congress.*

These images shows one of several Company Officers' Quarters at Albrook AFS. They are much larger than the civilian quarters located at the same installation. Additionally, they were built as permanent housing rather than temporary or early forms. Note the use of concrete throughout the building rather than wooden posts on concrete footings. The open floor plan with large windows and doors to let in light and air is typical of Panama Canal Zone architecture, as are the wide overhanging eaves. The shape of the plan, based off of these photographs, indicates that there is an open central area, possibly T-shaped.

These images are part of a larger group of photographs for the Company Officers' Quarters at Albrook Field. They were accessed through the online catalog for the Library of Congress. No architectural plans were located for this specific building.

Figure B.3: *Company Officers' Quarters, Living Space, Albrook AFS, PCZ. Image courtesy of the Library of Congress.*

Figure B.4: *Company Officers' Quarters, View of Living Space from Living Porch, Albrook AFS, PCZ. Image courtesy of the Library of Congress.*

Field Officers' Quarters

Location: Albrook AFS
Date of Photographs: 1990s

Figure B.5: *Field Officers' Quarters, Perspective View, Albrook AFS, PCZ. Image courtesy of the Library of Congress.*

Similar to the Company Officers' Quarters is the design for the Field Officers' Quarters at Albrook. The most obvious difference between the two is the scale. The Field Officers' Quarters are larger than those for the Company Officers'. Identifiable characteristics of PCZ architecture are all present in this building: Spanish tile cladding for the roof, large windows, concrete construction with a semi-open ground floor for air circulation, and an open interior floor plan with louvered transoms over doors and at the tops of interior walls to allow for improved air flow.

These images are part of a larger group of photographs for the Field Officers' Quarters at Albrook Field. They were accessed through the online catalog for the Library of Congress. No architectural plans were located for this specific building.

Figure B.6: *Field Officers' Quarters, Ground Floor, Albrook AFS, PCZ. Image courtesy of the Library of Congress.*

Figure B.7: *Field Officers' Quarters, Living Area, Albrook AFS, PCZ. Image courtesy of the Library of Congress.*

Non-Commissioned Officers' Quarters

Location: Albrook AFS
Date of Photographs: 1933

Figure B.8: *NCO Quarters, Perspective View, Albrook AFS, PCZ. Image courtesy of the Library of Congress.*

The Non-Commissioned Officers' Quarters are one of the larger designs of officers' quarters, standing at three stories tall. This particular design allowed for two apartments on the second and third floors, with a garage, storage, and likely a servants quarters on the ground floor. Each apartment was accessed by a rear exterior stair which can be seen in the image above. Due to their increased height, this design has the projecting intermediate roof form known as a "mediagua" above the window openings at the second level. This building component is meant to shed rain away from the openings and to allow light into the interior while deflecting direct sunlight. During the late 1950s and 1960s when air conditioning started to become standard and was installed in buildings in the Canal Zone that were constructed in the prior decades, screened-in open air sleeping porches were enclosed in order to seal the interior from the outside to prevent the escape of treated air. It is possible that this design originally had a sleeping porch on the second and third levels facing the street that is now enclosed.

These images are part of a larger group of photographs for the Non-Commissioned Officers' Quarters at Albrook Field. They were accessed through the online catalog for the Library of Congress. No architectural plans were located for this specific building.

Figure B.9: *NCO Quarters, Living Porch, Albrook AFS, PCZ. Image courtesy of the Library of Congress.*

Figure B.10: *NCO Quarters, Street View, Albrook AFS, PCZ. Image courtesy of the Library of Congress.*

BALBOA

Balboa was not planned as military installation. Instead, it was a town site developed in conjunction with the completion of the Panama Canal. As the Canal neared completion in 1914, Balboa quickly became the major town for the Pacific Terminus. During the planning and design stages of Balboa, it was intended that the site was to become the civic center of the Canal Zone.[159] Part of the site was developed using earth removed during the construction of the canal as fill. The fill area became known as Balboa Flats while the surrounding area in the hills became known as Balboa Heights. Balboa is situated adjacent to Panama City. The Military installations of Quarry Heights at Ancon Hill, Albrook Air Force Station, Fort Amador and Fort Clayton were constructed in the area surrounding Balboa.

[159] Crouch, *Architecture of the Panama Canal Zone*, 72.

Quarters Type 17

Location: Balboa
Date of Photograph: Unknown

Figure B.11: *Quarters Type 17, Front Perspective View, Balboa, PCZ. Image courtesy of the Library of Congress.*

This photograph shows one of the cottages constructed in Balboa Heights. Based on its method of construction, it likely represents some of the earliest housing constructed on the site. This is evident from the concrete footings and wooden piers that raise the main floor above grade. It is also wood frame construction rather than concrete. The date of the image is unknown. The description with the photograph merely states, "Type 17 Improved Cottage, Balboa Heights, C.Z." Drawings for a Type 17 Quarters built at Fort Amador are dated to 1916, which would confirm that it is one of the earliest types of housing. HABS photographs of the Fort Amador Type 17 Quarters indicate that it is identical in design to the quarters shown here. Please see Officer's Quarters - Type 17 for Fort Amador on page 181.

This image is from a collection of photographs of buildings and structures from the Panama Canal Zone. There is no clear organization to the collection, rather it is an amalgam of images. This photograph is the only image in the collection of this photograph. It is located at the National Archives in College Park, MD.

FORT AMADOR

Fort Amador was a U.S. Army and Navy installation located on the east side of the Canal at the Pacific entrance. It is often associated with Fort Grant which was a series of small fortified Islands in the Bay of Panama that were accessed by a causeway leading from Fort Amador. One of the first permanent fortifications to be constructed, Fort Amador was named after the Republic of Panama's first President, Manuel Amador Guerrero. Like portions of Balboa, Fort Amador was constructed on fill over what was originally swampland. While the Army portion of the Fort served to support the Coast Artillery personnel at Fort Grant, The Naval Station served as Headquarters for U.S. Navy activities in the Canal Zone from 1918 through 1993.[160]

[160] Crouch, *Architecture of the Panama Canal Zone*, 140.

Captain’s Quarters

Location: Fort Amador
Date of Drawings: 1916

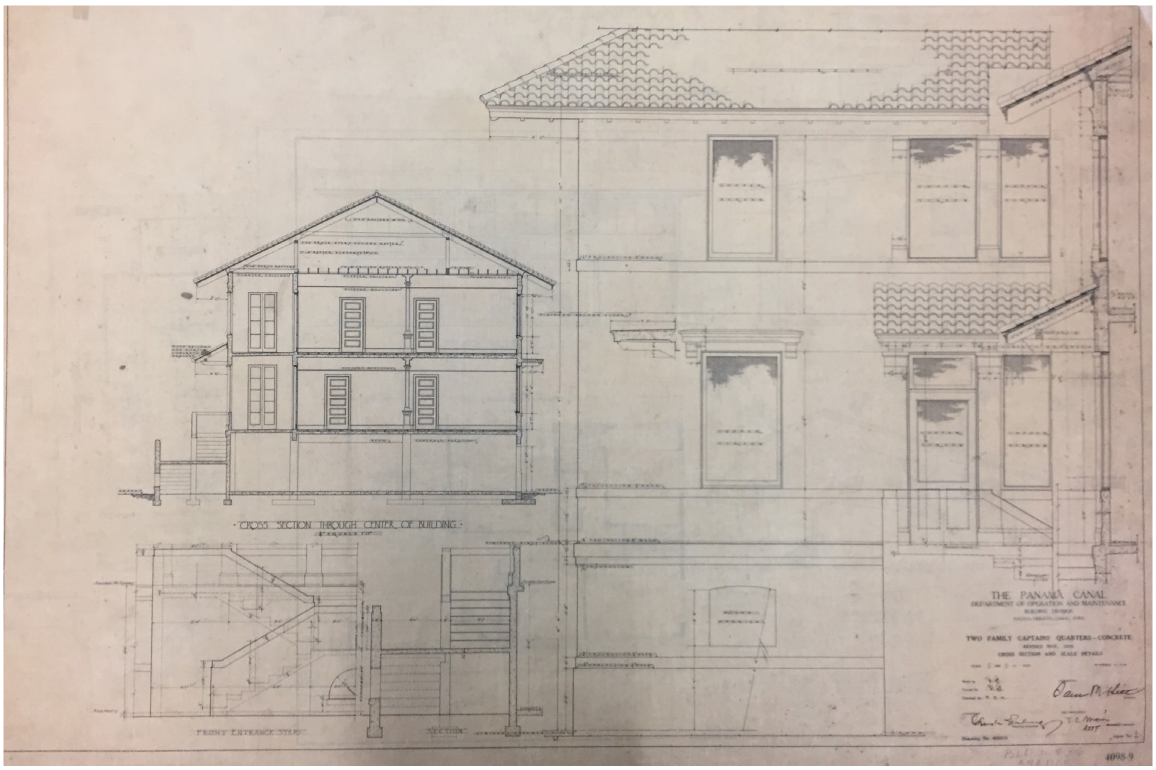

Figure B.12: *Captain’s Quarters, Elevation Detail and Section, Fort Amador, PCZ. Image courtesy of the National Archives and Records Administration.*

This design for Captain’s Quarters at Fort Amador is a three story structure on a raised, semi-open ground floor, typical of all PCZ architecture. The size and massing is similar to the Non-Com Officers’ Quarters located at Albrook AFS. One primary difference is, based on these drawings, the media agua at the second level does not run around the entire building. Instead it is located over the primary entrance at the second floor. The drawings on the following page show the floor plan and roof framing plan for the Captain’s Quarters. No photographs were located or identified for these quarters.

These drawings are part of a larger collection located in the National Archives in College Park Maryland. See References for further details.

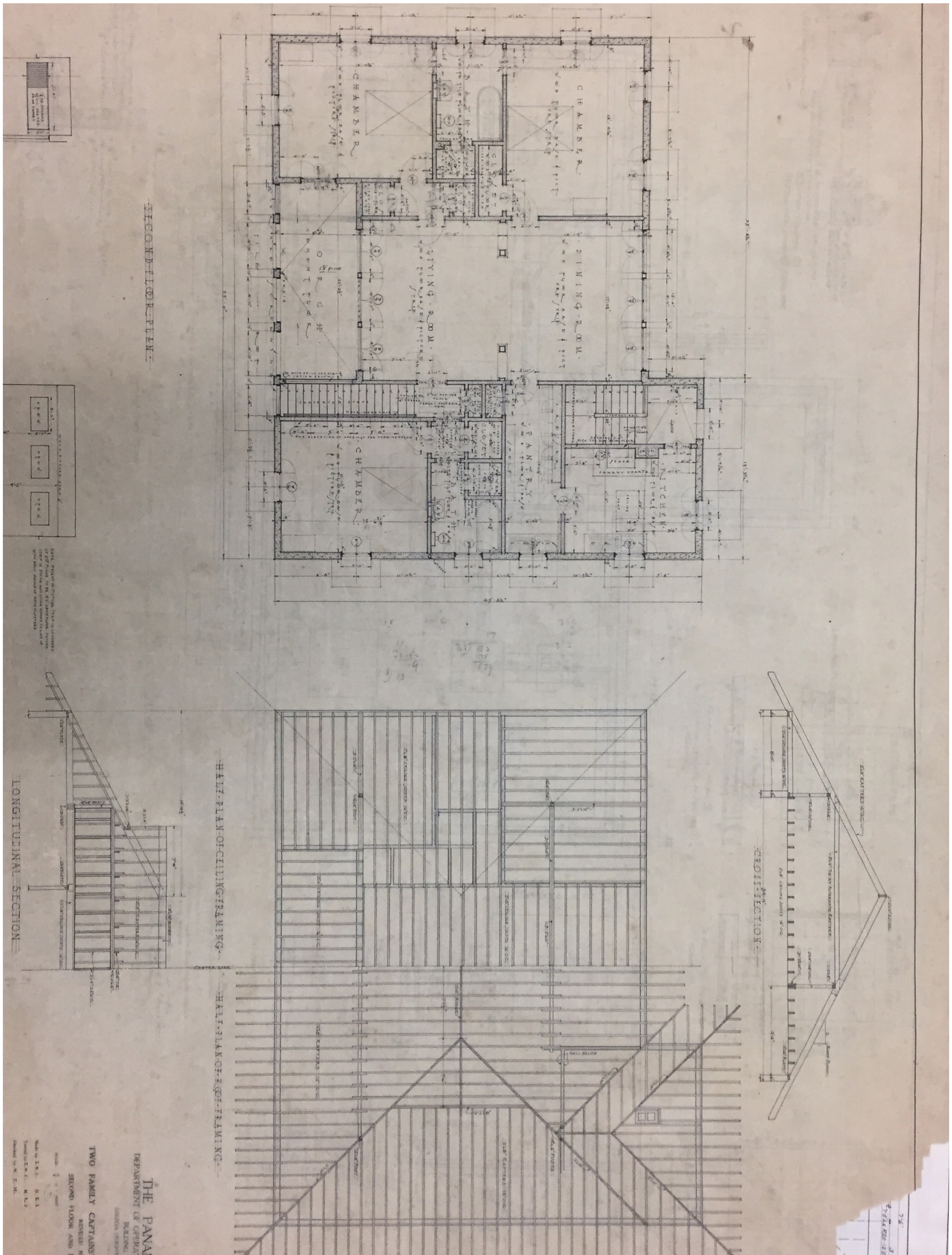

Figure B.13: *Captain's Quarters, Floor and Roof Framing Plans, Fort Amador, PCZ. Image courtesy of the National Archives and Records Administration.*

Commanding Officer's Quarters

Location: Fort Amador
Date of Drawings: 1914

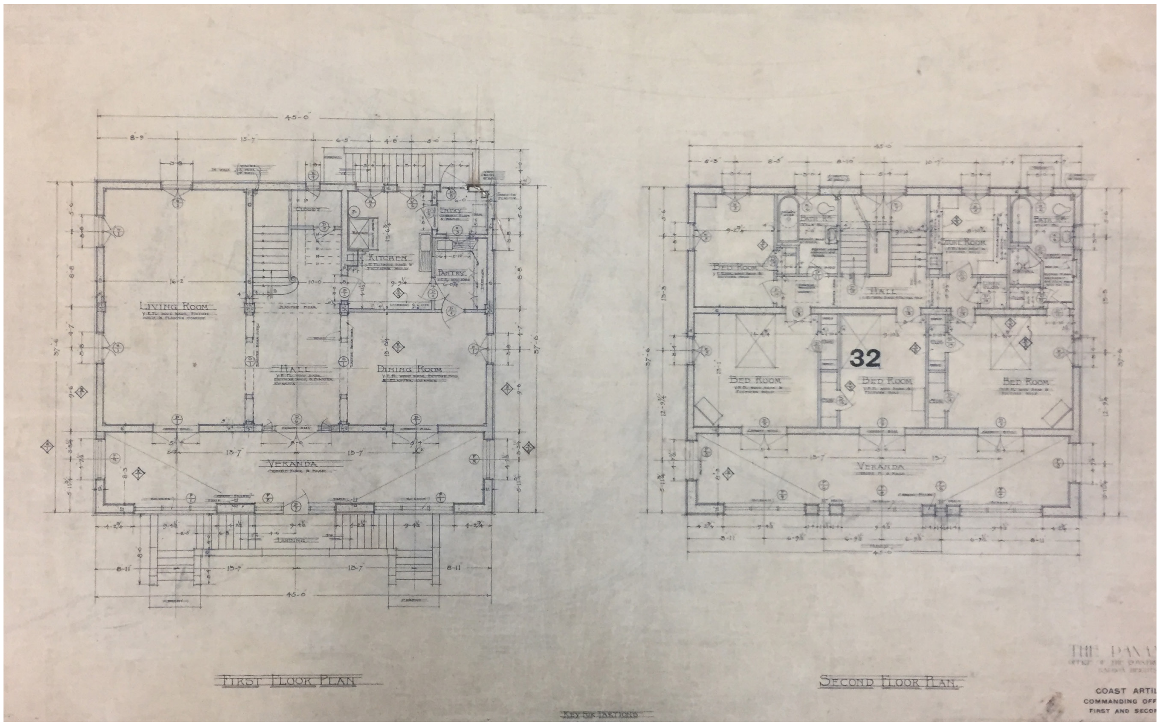

Figure B.14: *Commanding Officer's Quarters, First and Second Floor Plans, Fort Amador, PCZ. Image courtesy of the National Archives and Records Administration.*

The only drawing identified for this quarters type shows the floor plans for the first and second floors of the building. Based on the plan for the first floor, it can be assumed that there is a ground floor level below the first floor, as evident from the exterior stair required to access the first floor. Each floor has a veranda with large window openings, likely screened in to allow air flow through the house without letting insects inside. The verandas may have also been used as sleeping porches during particularly warm nights. Sleeping porches provided additional breezes to help cool the building occupants during the night. No photographs were identified during the research phase for this building type.

These plans are identical to those for Quarters Nos. 20, and 38. Please see plans for these quarters on pages 185-187 for additional details and comparison.

These drawings are part of a larger collection located in the National Archives in College Park Maryland. See References for further details.

Four Apartments: Van Hook Place

Location: Fort Amador
Date of Drawings: 1941
Date of Photographs: 1990s

Figure B.15: *Four Apartments: Van Hook Place, Front Elevation, Fort Amador, PCZ. Image courtesy of the Library of Congress.*

The Four Apartments of Four Van Hook Place are a less common type when it comes to officers' quarters. Most officers quarters are single units or double units which often have a family occupying each floor. This is due in part to wives of military personnel responding with a resounding no when the Corps of Engineers surveyed and asked whether women wold prefer apartments over housing. Although different in terms of their spatial layout and organization, the architectural elements for the Canal Zone type are all present. This example has particularly large expanses of windows which in this example are casement windows rather than sash. A mediagua runs the entire perimeter of the building above the first floow windows. The ground floor is largely open to allow for parking and air flow. Rather than being constructed entirely of reinforce concrete, this building has a reinforced concrete foundation and ground floor which supports the wood frame structure for the two floors of living space above. The drawings at right show the floor plan for the two main floors of the building, as well as a side elevation and section through the building.

These images and drawings are part of a larger group of photographs for the Four Apartments: Van Hook Place located at Fort Amador. They were accessed through the online catalog for the Library of Congress.

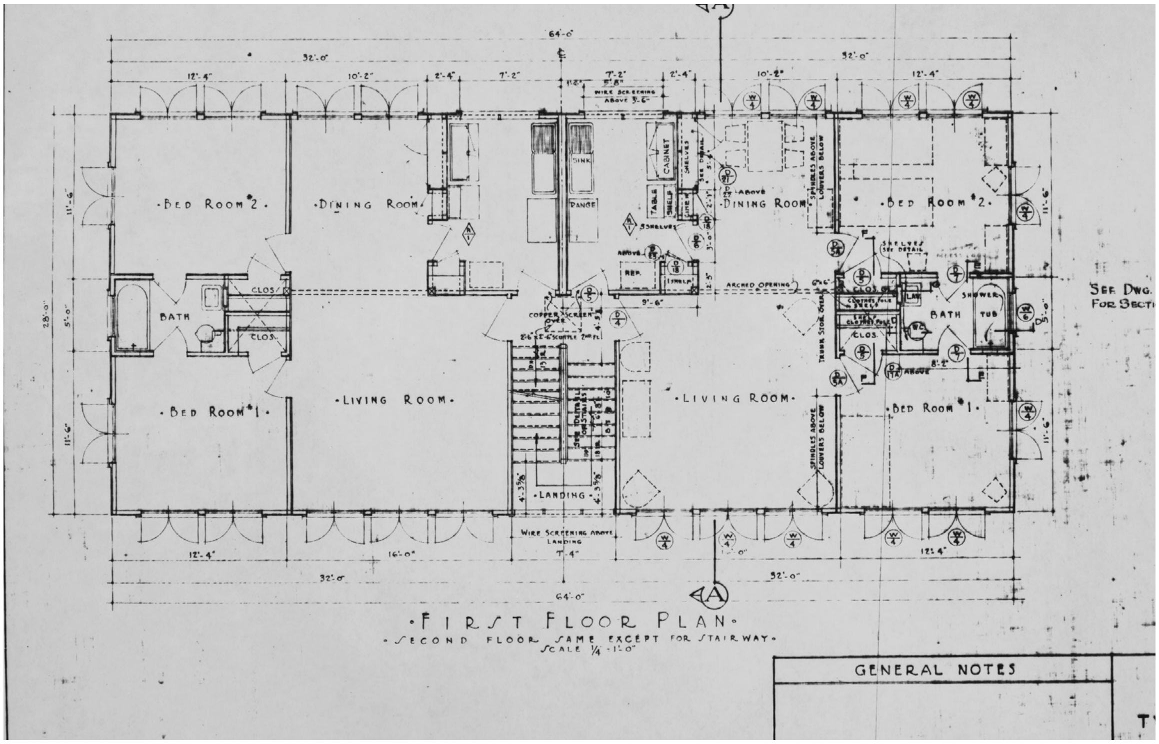

Figure B.16: *Four Apartments: Van Hook Place, First Floor Plan, Fort Amador, PCZ. Image courtesy of the Library of Congress.*

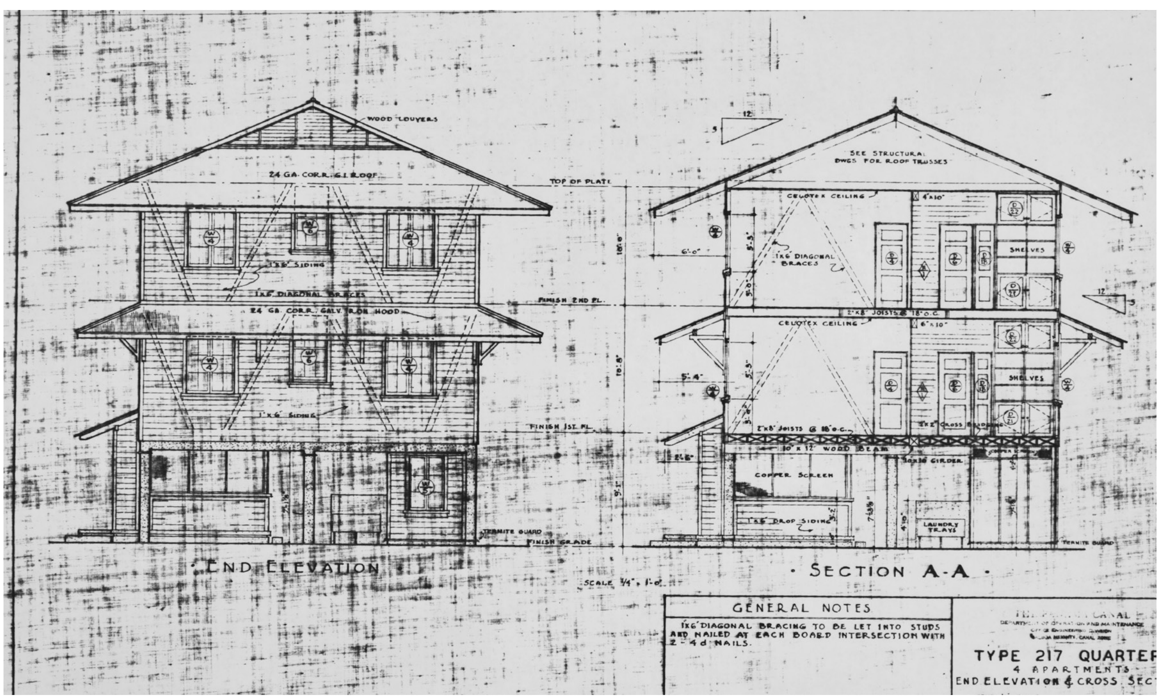

Figure B.17: *Four Apartments: Van Hook Place, Side Elevation and Section, Fort Amador, PCZ. Image courtesy of the Library of Congress.*

The images on these two pages show several of the architectural details of the apartments at Van Hook Place. Below is a detail of the wide eaves and exposed rafters. The image at top right shows the reinforced concrete that serves as the supporting structure for the floor above. At bottom right is an interior photo of the building showing exposed studs and framing members. Canal Zone buildings constructed using wood frame often had their interior walls exposed. This was because if the framing members of the walls were covered on the interior they became a prime breeding ground for rats.

Figure B.18: *Four Apartments: Van Hook Place, Detail of Eaves, Fort Amador, PCZ. Image courtesy of the Library of Congress.*

Figure B.19: *Four Apartments: Van Hook Place, Detail of Concrete Supports, Fort Amador, PCZ. Image courtesy of the Library of Congress.*

Figure B.20: *Four Apartments: Van Hook Place, Detail of Exposed Wall Studs, Fort Amador, PCZ. Image courtesy of the Library of Congress.*

Quarters No. 20

Location: Fort Amador
Date of Drawings: Unknown

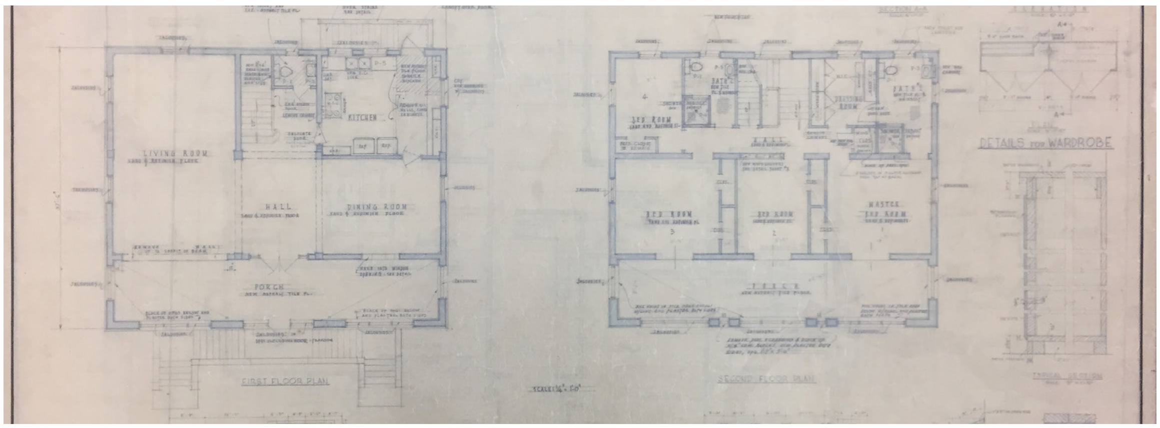

Figure B.21: *Quarters No. 20, First and Second Floor Plans, Fort Amador, PCZ. Image courtesy of the National Archives and Records Administration.*

This is the only drawing located during the research process that is associated with Quarters No. 20 at Fort Amador. What is interesting is that the floor plans are identical to the plans for the Commanding Officer's Quarters, also located at Fort Amador (you can view these plans on page 180), as well as Quarters No. 38. If this is true, then it indicates that the plans for this particular building form a standardized set that was used multiple times at Fort Amador. This was often the case as standardized designs were developed for use at military installations throughout a region. Designs often had additional variations that were derived from the initial standard design in order to cut design costs and provide efficiency. Quarters No. 40 also follows the same design but differs slightly due to an addition on one side. You can see the plans for Quarters No 40 on page 188

The plans show that the spatial layout of the first floor is relatively open, and the main facade of the building has sleeping porches on both floors. The plan also indicates that the primary circulation space, being the stairwell, hall and porch, forms a T-shape. The large windows and spatial organization with large doorways allow for improved air flow. The image at right is an enlarged portion of the drawing above, showing the first floor plan in greater detail.

These drawings are part of a larger collection located in the National Archives in College Park Maryland. See References for further details.

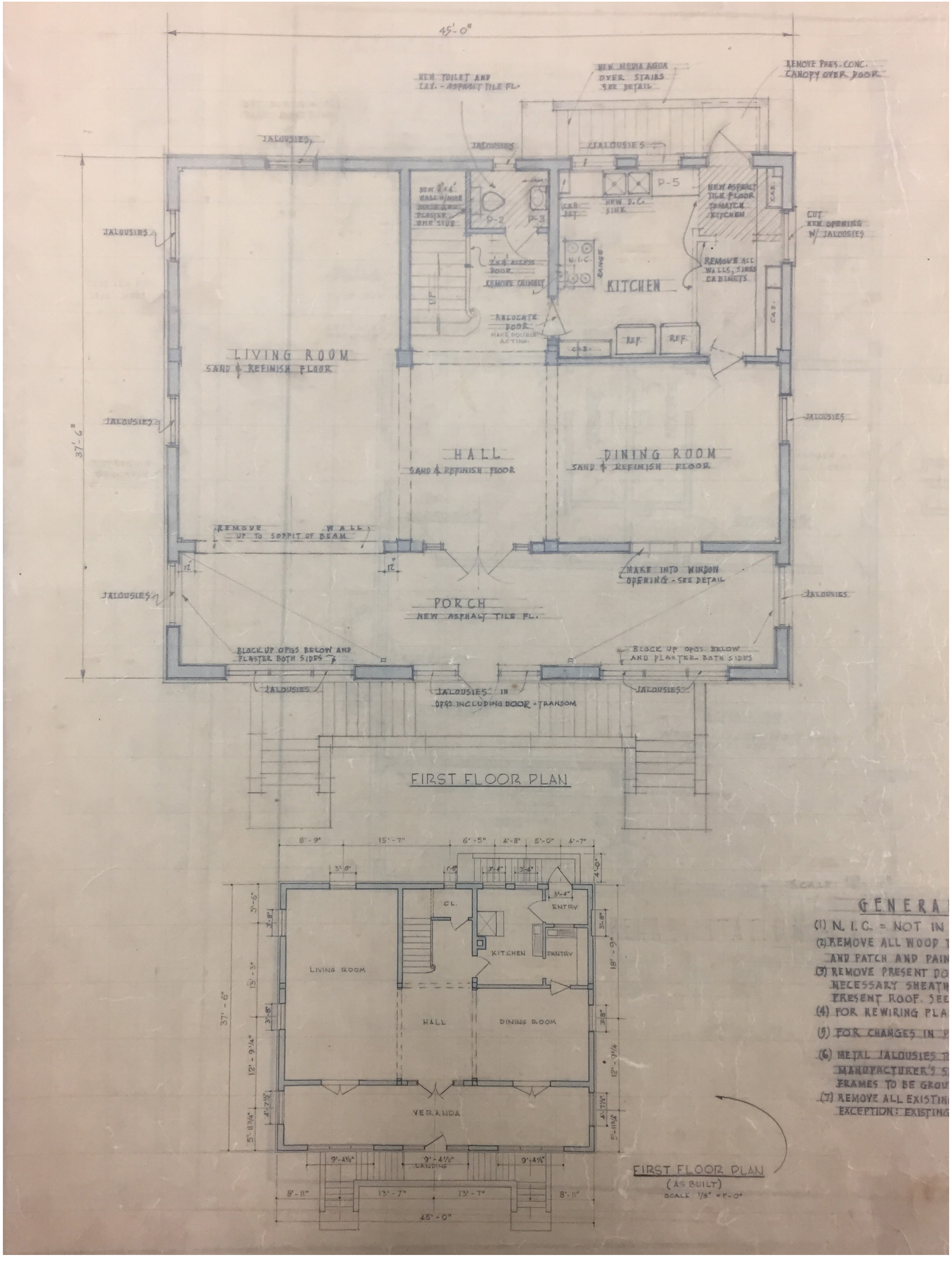

Figure B.22: *Quarters No. 20, First Floor Plan, Fort Amador, PCZ. Image courtesy of the National Archives and Records Administration.*

Quarters No. 38

Location: Fort Amador
Date of Drawings: 1953

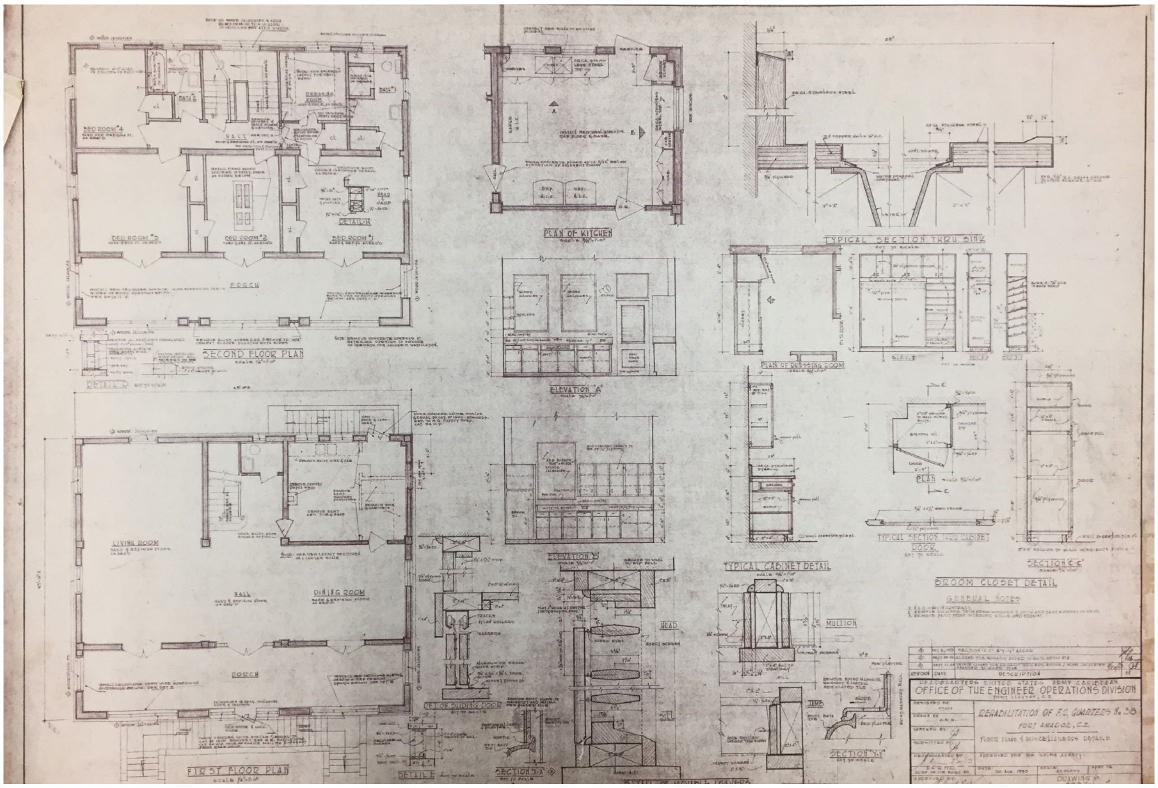

Figure B.23: *Quarters No. 38, First and Second Floor Plans and Details, Fort Amador, PCZ. Image courtesy of the National Archives and Records Administration.*

This sheet of drawings is the same design used in Quarters 20 and the Commanding Officer's Quarters. Quarters No. 40 on the opposite page is also of the same design but with an addition on its left side.

These drawings are part of a larger collection located in the National Archives in College Park Maryland. See References for further details.

Quarters No. 40

Location: Fort Amador
Date of Drawings: 1965

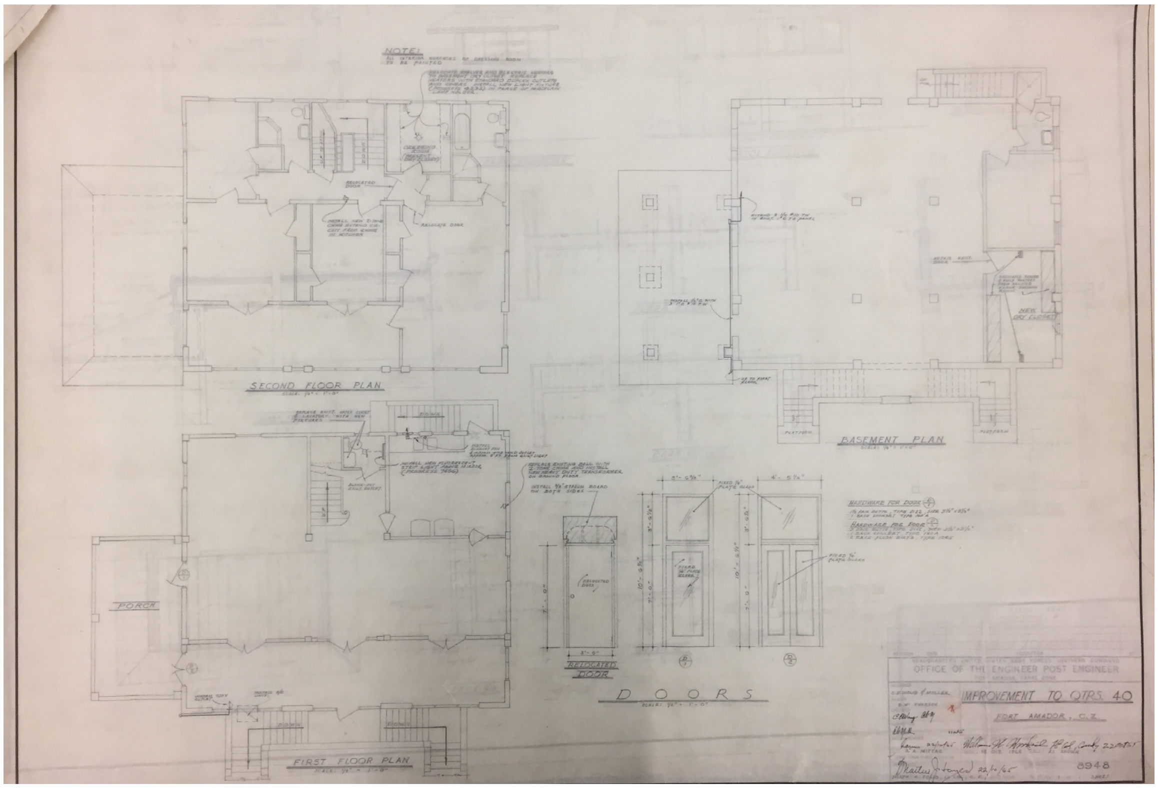

Figure B.24: *Quarters No. 40, Floor Plans, Fort Amador, PCZ. Image courtesy of the National Archives and Records Administration.*

Quarters No. 40 deviates slightly from the standardized plans used in Quarters 20 and 38. The plans are identical except in this instance they have been altered through the addition of a porch on the first floor level on the left elevation. It is possible that this design as one of the 'Type' plans that devleoped from the initial standardized set. Quarters No. 42 on the following page has a similar addition and slightly different floor plan.

These drawings are part of a larger collection located in the National Archives in College Park Maryland. See References for further details.

Quarters No. 42

Location: Fort Amador
Date of Drawings: 1958

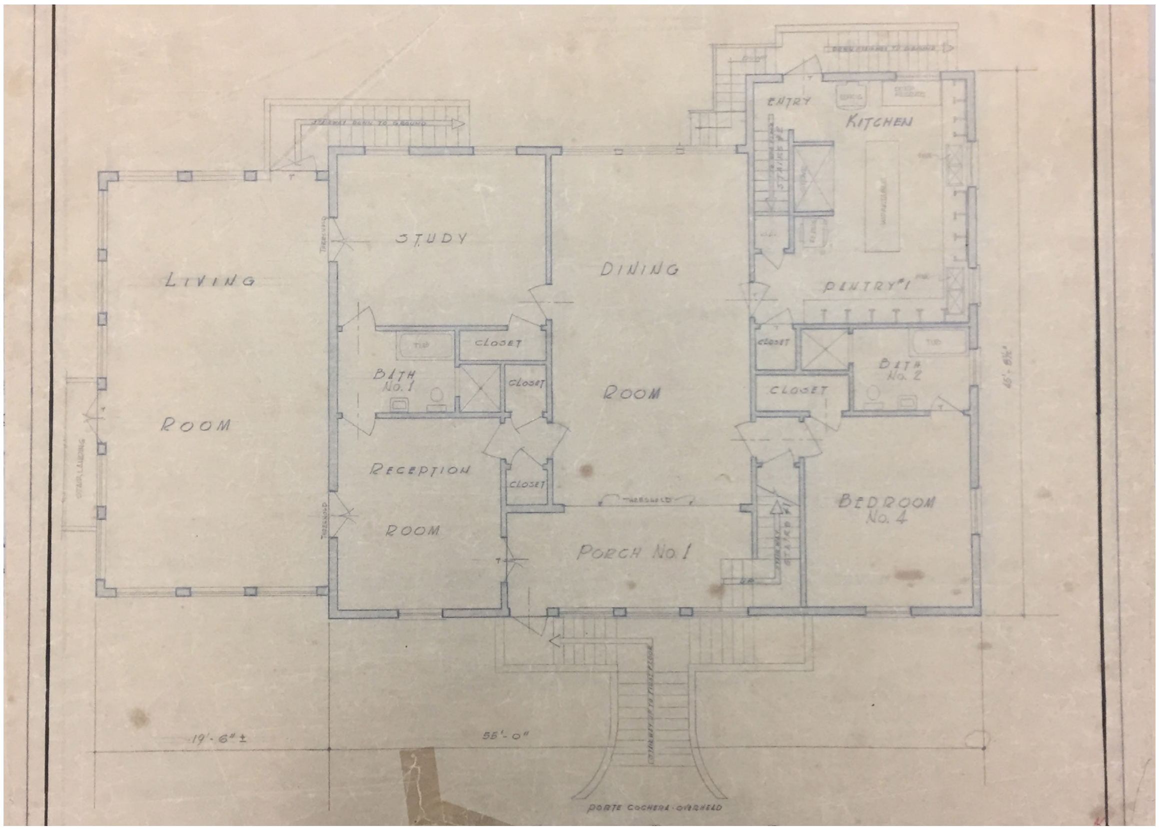

Figure B.25: Quarters No. 42, First Floor Plan, Fort Amador, PCZ. Image courtesy of the National Archives and Records Administration.

Quarters No. 42, although similar to the preceding examples which follow the same floor plan, is distinct because its spatial organization has been altered. No longer does a wide porch span the length of the front facade; instead, it has been truncated to allow for additional interior living space. A bedroom has been added to the first floor, a feature that is not present in the plans for the other quarters. Additionally, the kitchen has been expanded outward away from the building. Like No. 40, Quarters No. 42 has an addition on its left elevation. However, this addition is slightly larger, running the full height of the building with a garage on the ground floor, Living Room and Porch on the first floor, and veranda on the second floor. It also differs slightly in the design for the front set of stairs which provide access to the first floor of the building.

These drawings are part of a larger collection located in the National Archives in College Park Maryland. See References for further details.

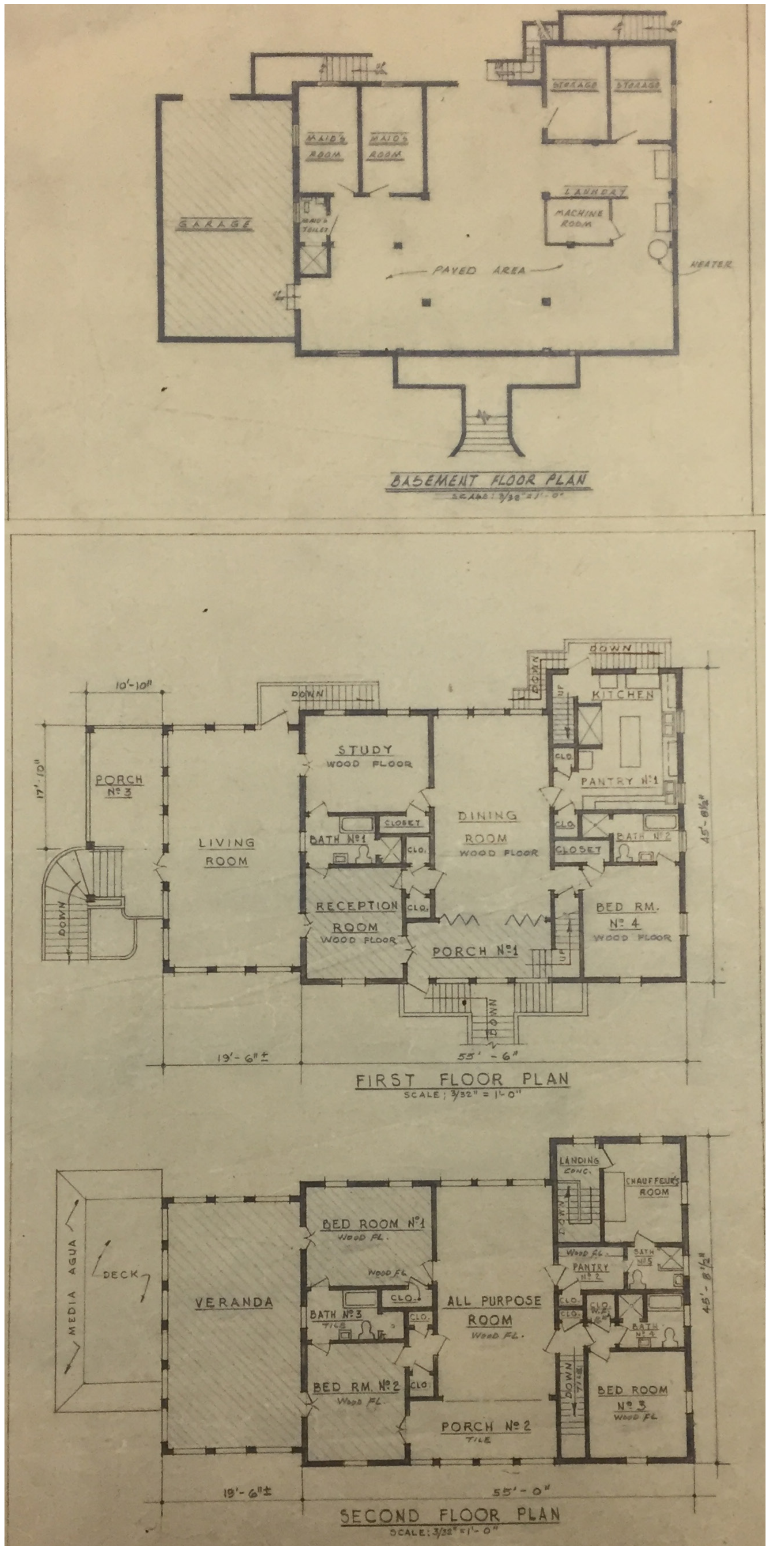

Figure B.26: *Quarters No. 42, Floor Plans, Fort Amador, PCZ. Image courtesy of the National Archives and Records Administration.*

Officer’s Quarters - Type 17

Location: Fort Amador
Date of Drawings: 1917
Date of Photographs: 1990s

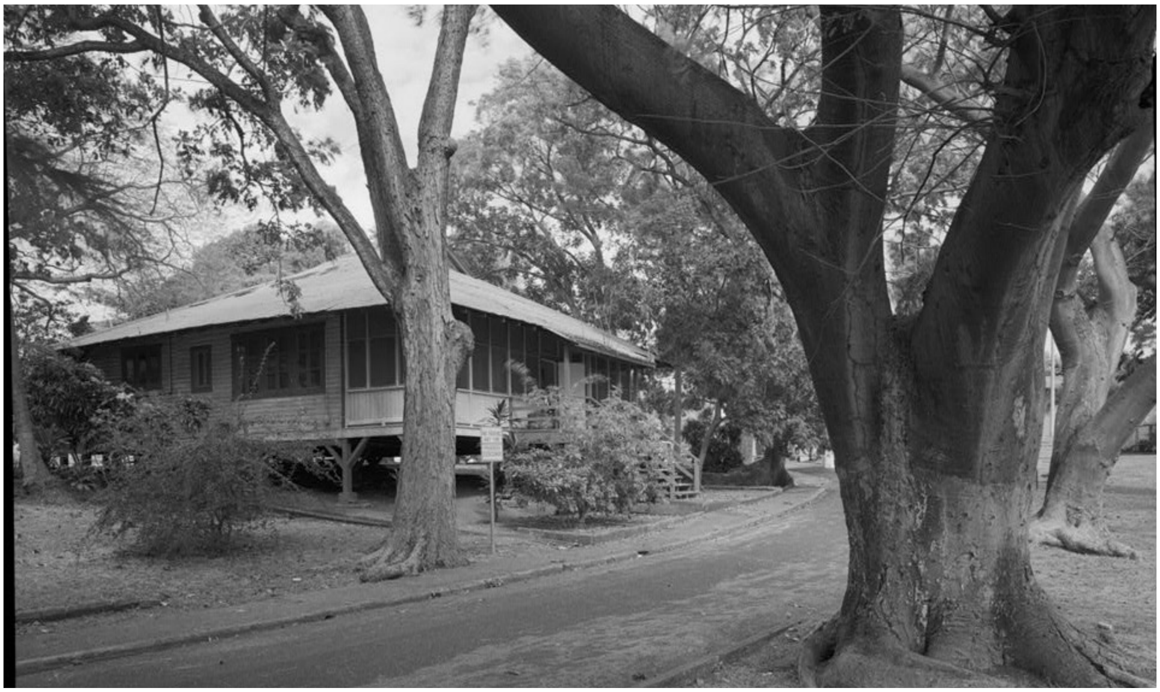

Figure B.27: *Officer’s Quarters Type 17, Street View, Fort Amador, PCZ. Image courtesy of the Library of Congress.*

The photographs and architectural drawings for Type 17 indicates that this was likely a set of standardized plans used at multiple locations. This notion is further strengthened by the presence of at least one Type 17 quarters in Balboa Heights. In both cases, the same method of construction is followed. Concrete footings support wooden piers to elevate the building off the ground, allowing air to circulate beneath the house which aids in cooling. The wooden piers support the single floor of the house, which is constructed using wood frame. The interior walls likely leave the studs exposed in order to prevent rats from getting into the walls and breeding. A screened-in porch runs the entire length of the front facade of the building, providing an outdoor living space cooled by the breeze yet safe from mosquitoes. The architectural drawings on the right depict the first floor plan which shows the spatial layout of the building, and the front elevation and one of the side elevations. Photographs of some of the architectural details are on the following two pages.

These images and drawings are part of a larger collection of photographs for Fort Amador Officer’s Quarters. They were accessed through the online catalog for the Library of Congress.

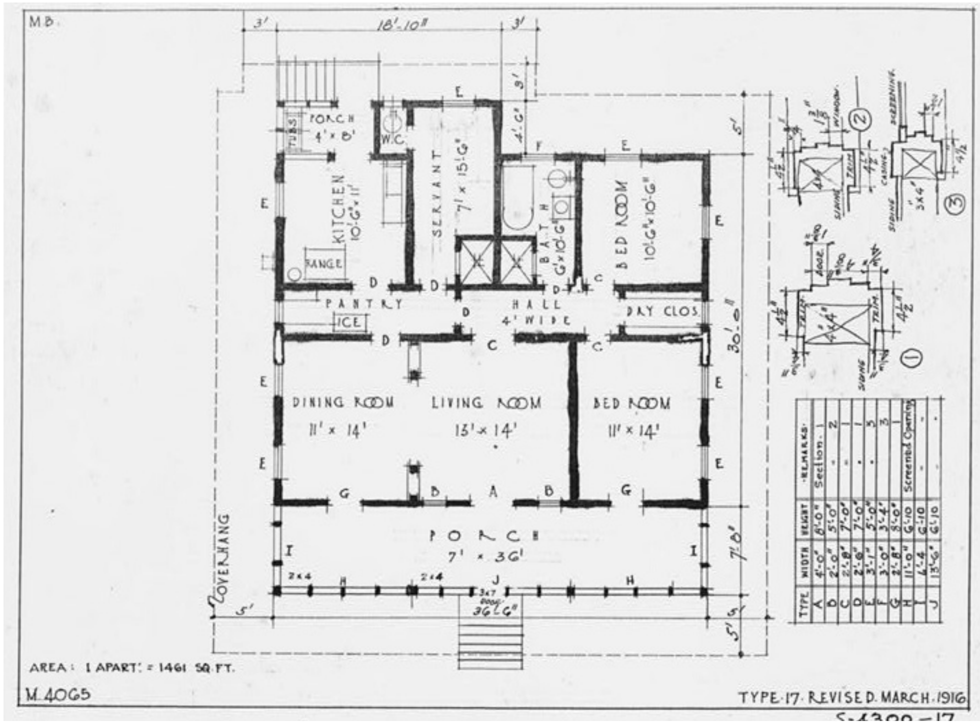

Figure B.28: *Officer's Quarters Type 17, Floor Plan, Fort Amador, PCZ. Image courtesy of the Library of Congress.*

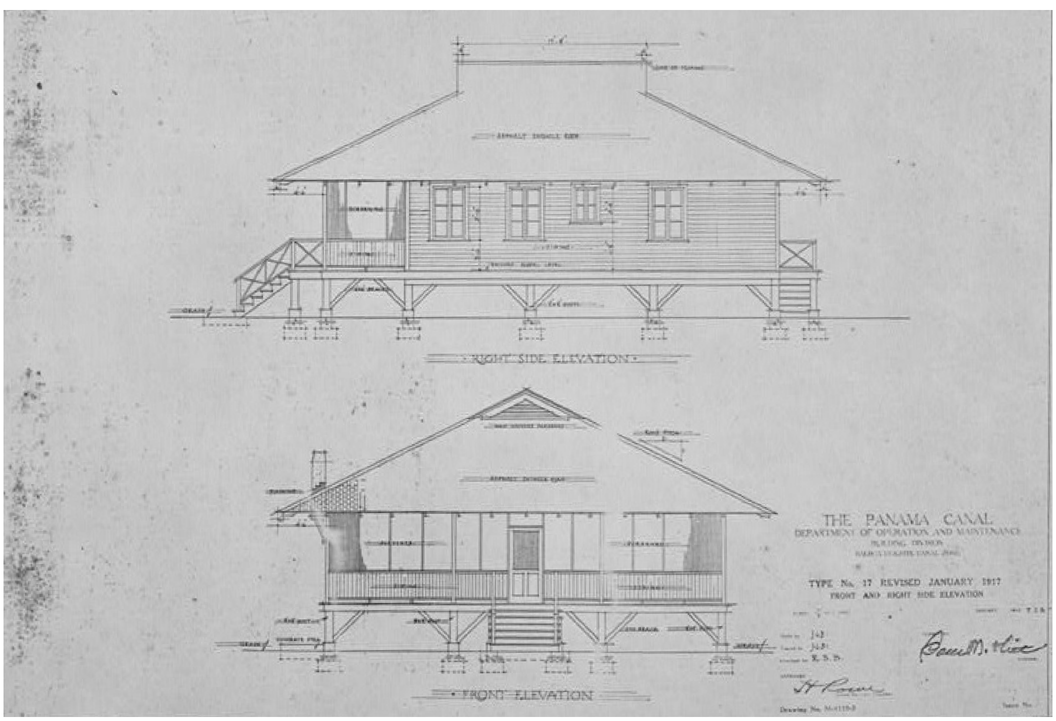

Figure B.29: *Officer's Quarters Type 17, Elevations, Fort Amador, PCZ. Image courtesy of the Library of Congress.*

The images on these two pages show Type 17 in greater detail. In the image below you can see the concrete footings and wooden piers that support the building. While some early housing types were constructed with wooden piers lifting the main floor of the building an entire story, these only lift the building approximately three to four feet off the ground. The top-right photograph on the opposite page shows that the interior was finished, but the large whole in the wall at the center of the photo reveals the underlying studs. and wall cladding on the opposite side. From this image it appears that the stud and cladding are finished, indicating that they were likely left exposed when the house was originally built. The image on the bottom-right shows the screened in living porch which served as an extension of the living space of the house. Note how the wide overhanging eaves block direct solar energy while still allowing in light.

Figure B.30: *Officer's Quarters Type 17, Perspective View, Fort Amador, PCZ. Image courtesy of the Library of Congress.*

Figure B.31: *Officer's Quarters Type 17, Living/Dining Room, Fort Amador, PCZ. Image courtesy of the Library of Congress.*

Figure B.32: *Officer's Quarters Type 17, Living Porch, Fort Amador, PCZ. Image courtesy of the Library of Congress.*

FORT CLAYTON

Fort Clayton was a U.S. Army installation located on the east side of the Canal north of Balboa and Forts Amador and Grant. The fort is situated next to the Miraflores locks which it was intended to protect. It was the first infantry post constructed on the Pacific side, and like many of the other military installations, it was built on fill from the construction of the Canal which became known as the Miraflores Dumps. Throughout its years of operation, Fort Clayton saw various periods of growth and expansion, particularly during the 1930s and World War II.[161]

[161] Crouch, *Architecture of the Panama Canal Zone*, 146.

Officer's Quarters

Location: Fort Clayton
Date of Photograph: 1935

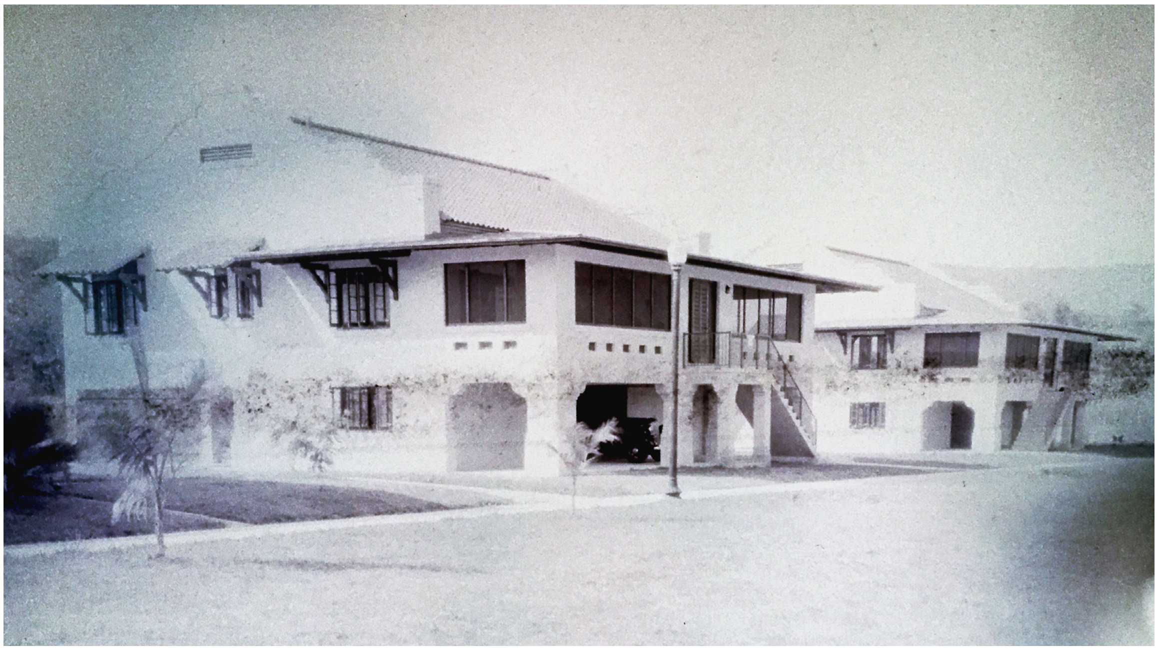

Figure B.33: *Officer's Quarters, Perspective View, Fort Clayton, PCZ. Image courtesy of the National Archives and Records Administration.*

This photograph shows two buildings serving as Officer's Quarters at Fort Clayton. The design for these buildings is unique in that it does not completely coincide with typical Canal Zone architecture. Rather than have a hipped roof, the roof on these buildings is a gable with wide, scalloped gable ends. This is one of the elements of Spanish Colonial Revival Design that was being used at military installations across the Southern United States at the time. While the building does appear to be constructed of reinforced concrete with a partially open ground floor, the use of a gable roof prevents the wide eaves from running the entire perimeter of the building. Instead, windows at the gable ends on the the main level of the house have individual coverings that shade them from direct sunlight (the size and design of these does not quite coincide with mediaguas). These buildings are an exception to the standard architectural design in the Panama Canal Zone.

This image is one of two photograph negatives showing these quarters. The other photo looks toward the opposite gable to produce a nearly mirror image of the one above. Together, they are in a collection of negatives which show U.S. Army Facilities in the Panama Canal Zone from 1935-1937. The negatives can be found in Record Group 395-PF of the National Archives in College Park, Maryland.

Field Officer's Quarters

Location: Fort Clayton
Date of Drawings: 1933

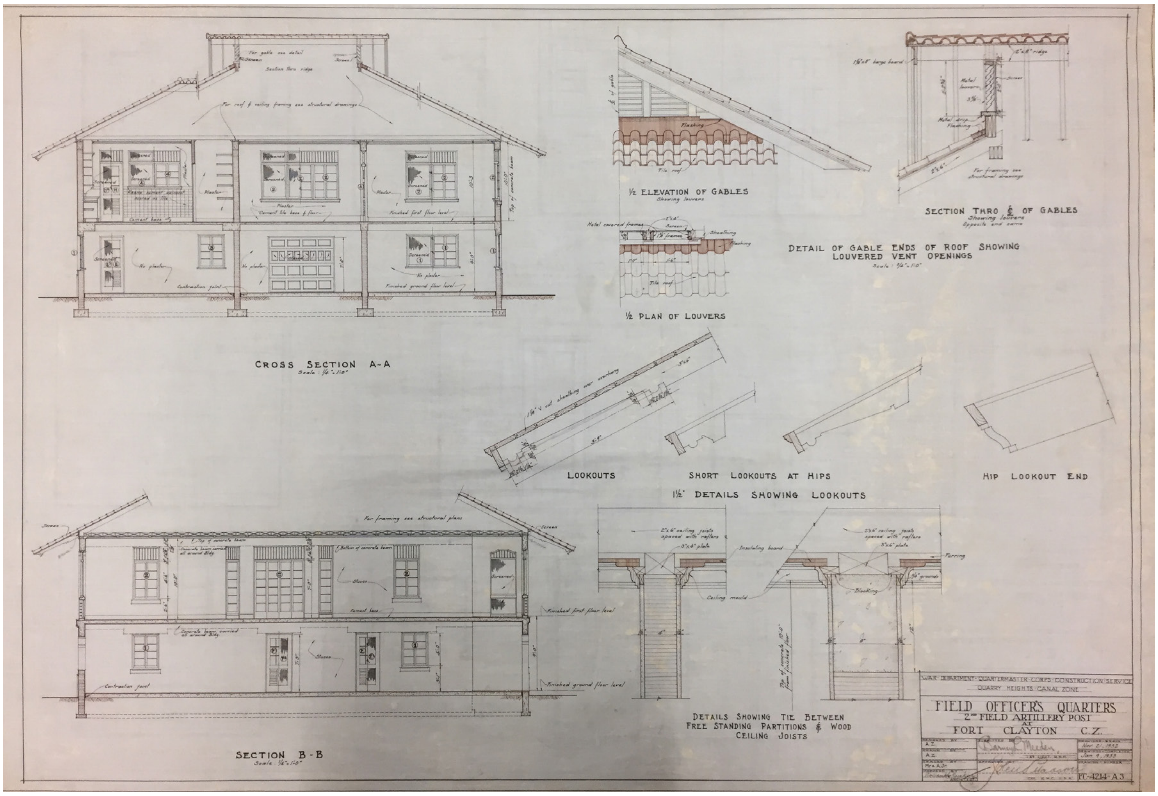

Figure B.34: *Field Officer's Quarters, Sections and Details, Fort Clayton, PCZ. Image courtesy of the National Archives and Records Administration.*

The Field Officer's Quarters at Fort Clayton is an example of permanent quarters constructed using reinforced concrete. The spatial organization of the building puts the primary living quarters on the first floor, with secondary spaces and quarters for the maid or servant on the ground floor, as was typical of officer's quarters in the canal zone. Large casement windows improve the cooling ability of the building due to their ability to be angled to catch the breeze in the most effective manner. Exterior lateral stairs provide access to the first floor at the porch at the front of the house, and the kitchen at the rear. The porch extends across the front elevation and partially wraps around one side. The main central or circulatory space remains the same with a central hallway running from the front to the back of the building which opens onto the porch. This forms a crude T-shape in plan.

These drawings are part of a larger collection located in the National Archives in College Park Maryland. See References for further details.

Figure B.35: *Field Officer's Quarters, Elevations, Fort Clayton, PCZ. Image courtesy of the National Archives and Records Administration.*

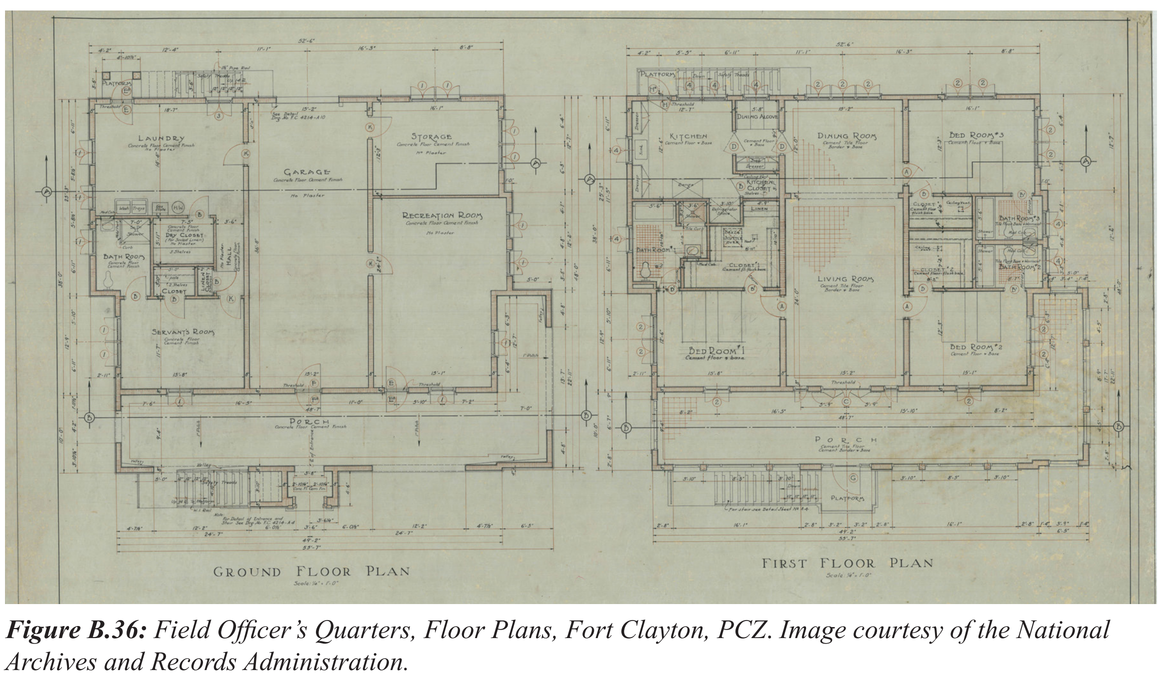

Figure B.36: *Field Officer's Quarters, Floor Plans, Fort Clayton, PCZ. Image courtesy of the National Archives and Records Administration.*

FORT DAVIS

Fort Davis is a former U.S. Army installation located along the shores of Gatun Lake in the Panama Canal Zone. Originally known as Camp Gatun, Fort Davis was constructed in 1920 with the purpose of protecting the Gatun Locks at the Atlantic side of the Canal. During its period of operation, specifically during the Vietnam War era, Fort Davis was used as a training ground for jungle warfare and special operations.[162]

[162] Crouch, *Architecture of the Panama Canal Zone*, 149.

Field Officer’s Quarters

Location: Fort Davis
Date of Drawing: 1931

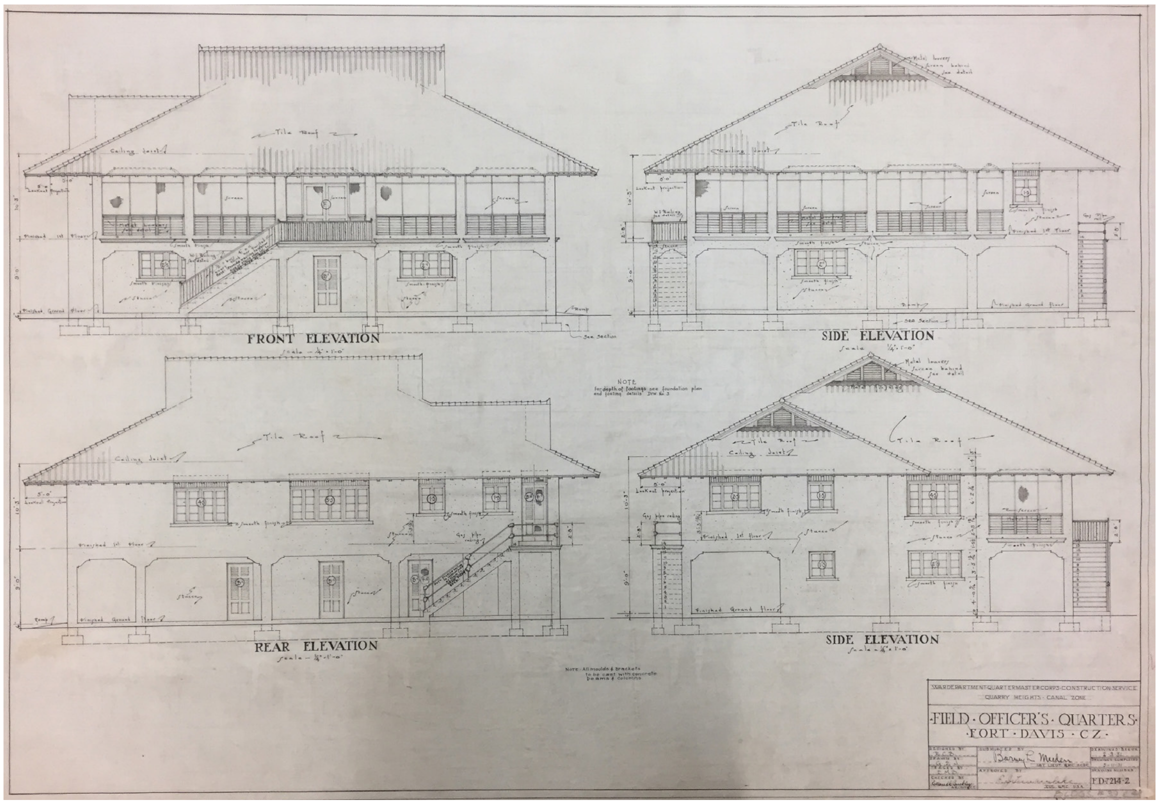

Figure B.37: *Field Officer’s Quarters, Elevations, Fort Davis, PCZ. Image courtesy of the National Archives and Records Administration.*

The design for this set of Field Officer’s Quarters at Fort Davis are similar in design to the Field Officer’s Quarters at Fort Davis which can be seen on the previous two pages. The primary difference in this design is that the ground floor is much more open and the porch extends even further along the side elevation, which is the top-right elevation in the drawing above. The smaller hipped roof protruding from the main hipped roof of the building has its own separate louvered vent at the ridge of the roof, similar to those on the roof over the main body of the house. The Quarters at Fort Clayton do not have this additional louvered vent.

These drawings are part of a larger collection located in the National Archives in College Park Maryland. See References for further details.

FORT SHERMAN

Fort Sherman is another former U.S. Army installation in the Canal Zone. Designated in 1911 with troops stationed by 1915, Fort Sherman was one of the earliest U.S. military installations to be established in the area. Located on Limon Bay on the the west side of the Atlantic entrance to the Panama Canal, the fort was constructed to defend the harbor and canal entrance from attack.

Double NCO Quarters Type 6

Location: Fort Sherman
Date of Drawing: 1939

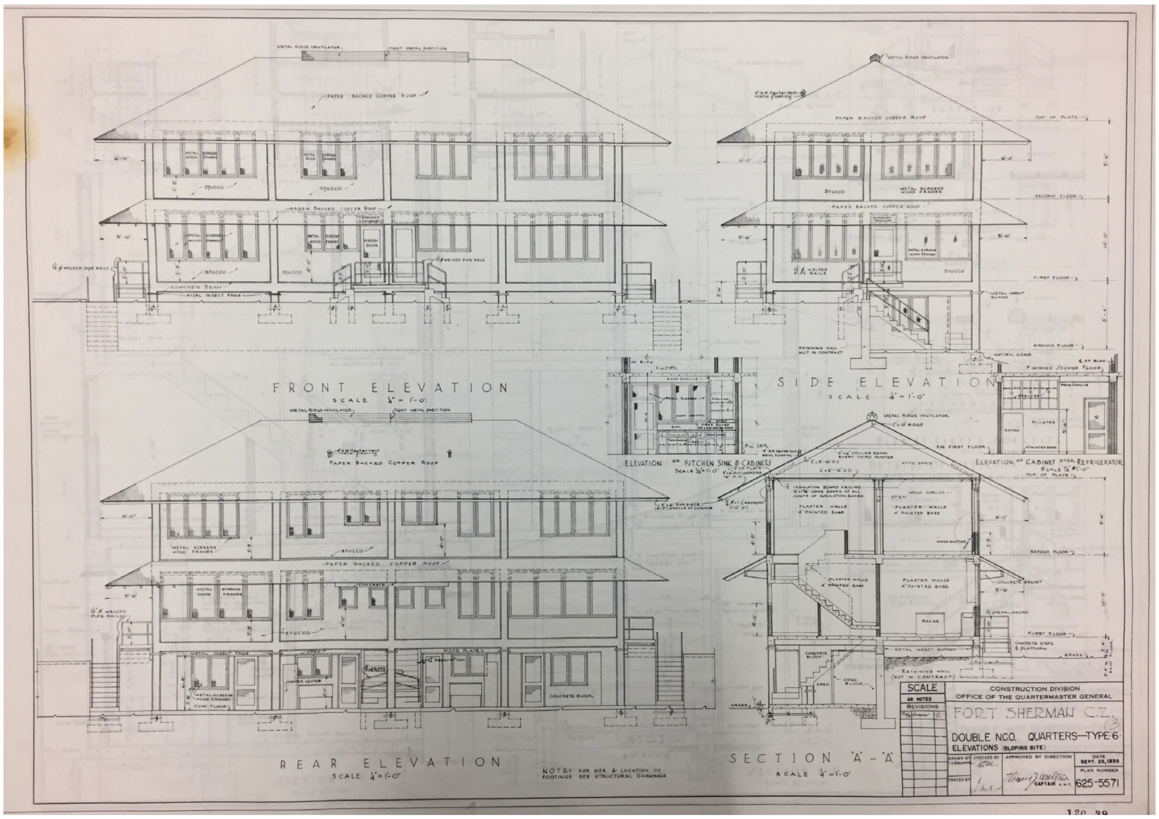

Figure B.38: *Double NCO Quarters Type 6, Elevations and Section, Fort Sherman, PCZ. Image courtesy of the National Archives and Records Administration.*

The above elevations appear to indicate that this building is meant to be constructed on a hillside. This prevents the ground floor or basement from being completely open to outside air. Butting against the earth, however, likely aids in keeping the ground floor cool. The design is similar to the Four Apartments at Van Hook Place located at Fort Amador except in this case each side is a single two-story duplex rather than individual apartments on each floor. Note the mediagua running the length of each elevation of the building. Casement windows are an important part of the design for passive cooling prior to the advent of air conditioning.

These drawings are part of a larger collection located in the National Archives in College Park Maryland. See References for further details.

Duplex CO Quarters Type 2

Location: Fort Sherman
Date of Drawing: 1939

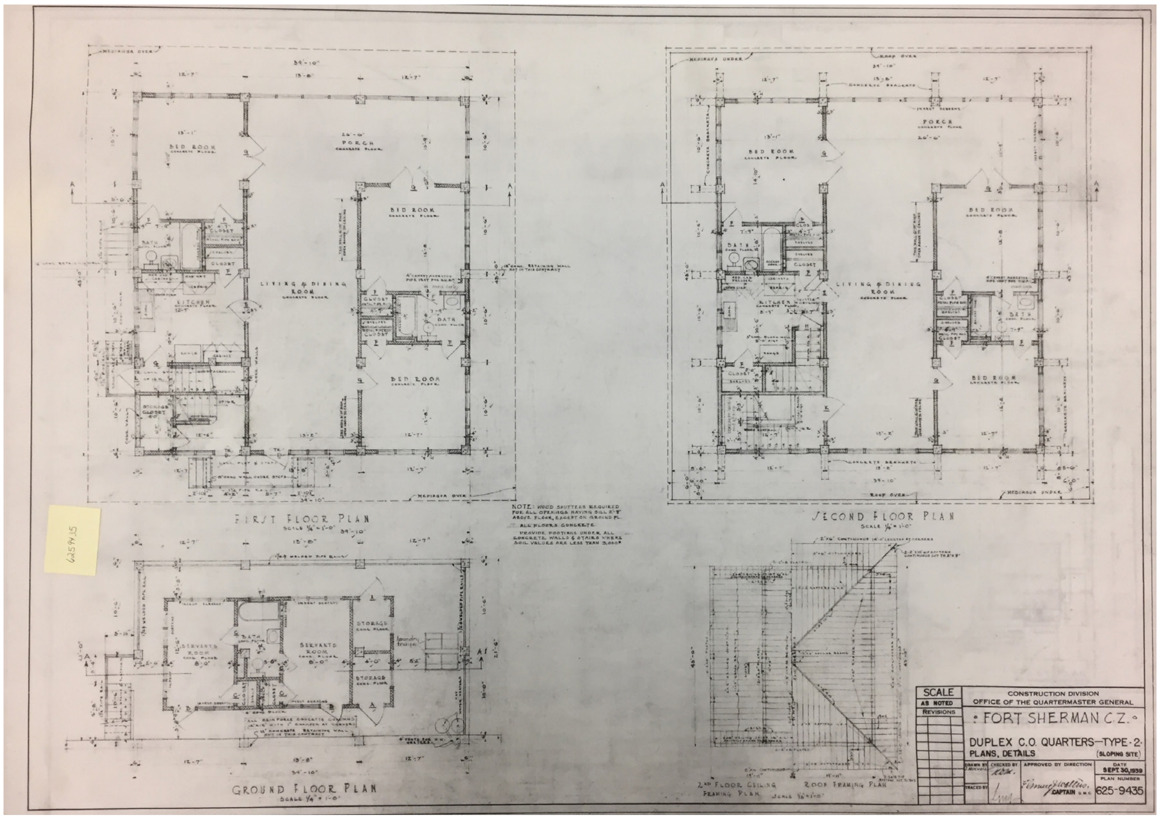

Figure B.39: *Duplex CO Quarters Type 2, Floor Plans, Fort Sherman, PCZ. Image courtesy of the National Archives and Records Administration.*

The Duplex CO Quarters is essentially designed as two apartments stacked with one on top of the other, both having the same floor plan. Rather than being completely separate however, the two are attached on the interior with a stairwell. A third bedroom at the rear-left of each floor plan alters the central multi-purpose living space that runs through the center of the house into a rough L shape rather than a T shape. The square piers present in every plan in the drawing indicate that the building is constructed using reinforced concrete at all levels rather than wood frame. This method of construction was the standard by 1939 for permanent quarters.

These drawings are part of a larger collection located in the National Archives in College Park Maryland. See References for further details.

Duplex NCO Quarters Type 1

Location: Fort Sherman
Date of Drawing: 1939

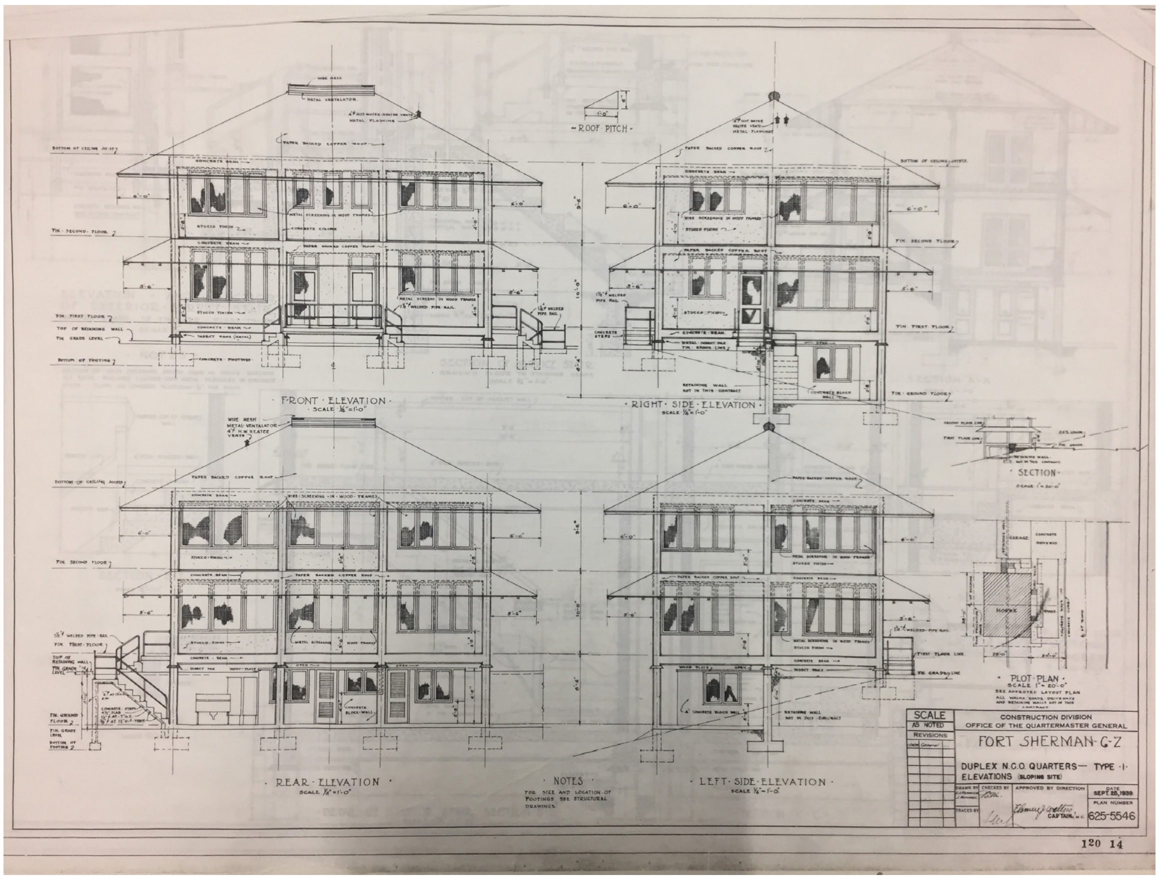

Figure B.40: *Duplex NCO Quarters Type 1, Elevations, Fort Sherman, PCZ. Image courtesy of the National Archives and Records Administration.*

Although similar in appearance to the Double NCO Quarters Type 6 featured on the previous spread, this design calls for a building slightly smaller in size. The primary architectural features remain the same as the Type 6 quarters; the design even indicates that the building is to be constructed on a hillside. Apart from being smaller in size, the building appears to have significantly fewer casement windows in its rear facade according to this drawing.

These drawings are part of a larger collection located in the National Archives in College Park Maryland. See References for further details.

Single CO Quarters Type 3

Location: Fort Sherman
Date of Drawings: 1939

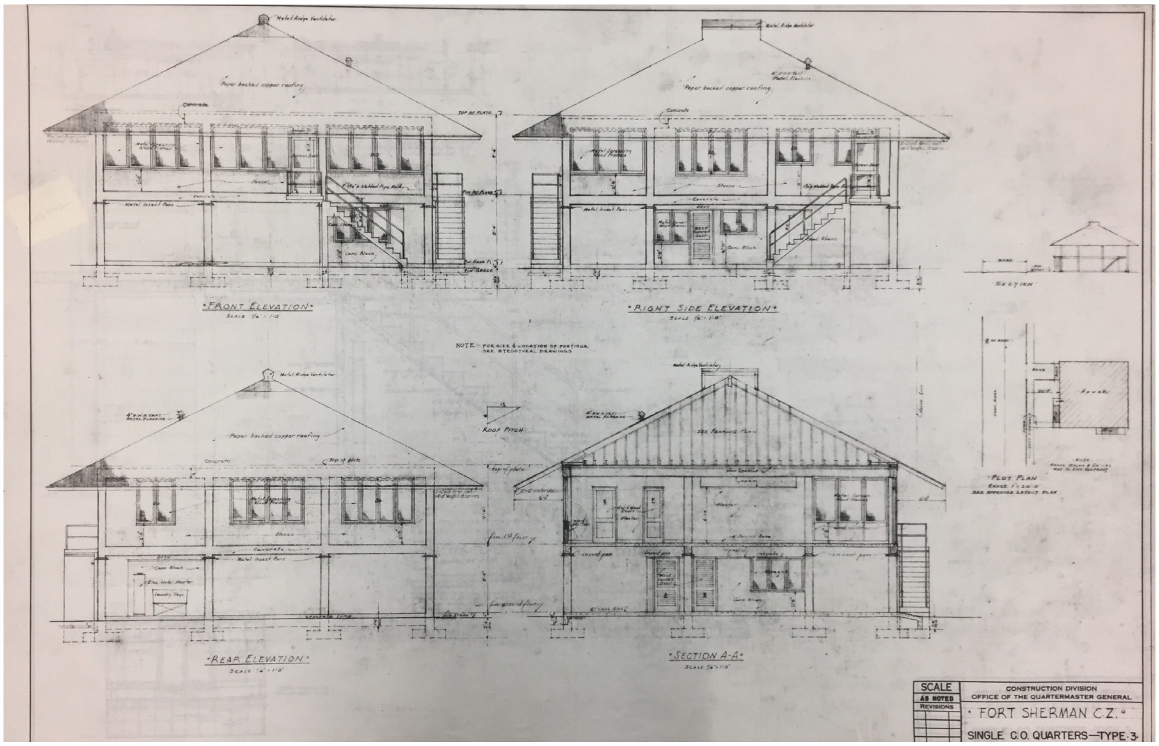

Figure B.41: *Single CO Quarters Type 3, Elevations and Section, Fort Sherman, PCZ. Image courtesy of the National Archives and Records Administration.*

Although constructed at a later date, this design for Single CO Quarters Type 3 bears resemblance to the Civilian Quarters at Albrook AFS as well as the Type 17 quarters located at Balboa and Fort Amador. The method of construction is clearly different here, however, with the use of concrete throughout the entire structure rather than simply in the footings. The ground floor is left nearly entirely open, with only a servants quarters and storage room present. The design of the first floor is important: the central portion of the plan is entirely open, forming a T-shape with a porch forming the top of the T and a multi-use living space forming the central portion. This is flanked on one side by two bedrooms which share a bathroom, and on the other with a single larger bedroom and kitchen with a bathroom situated between them. The building is nearly square in plan with a low-pitched hip roof with vents at its ridge, and casement windows along each elevation.

These drawings are part of a larger collection located in the National Archives in College Park Maryland. See References for further details.

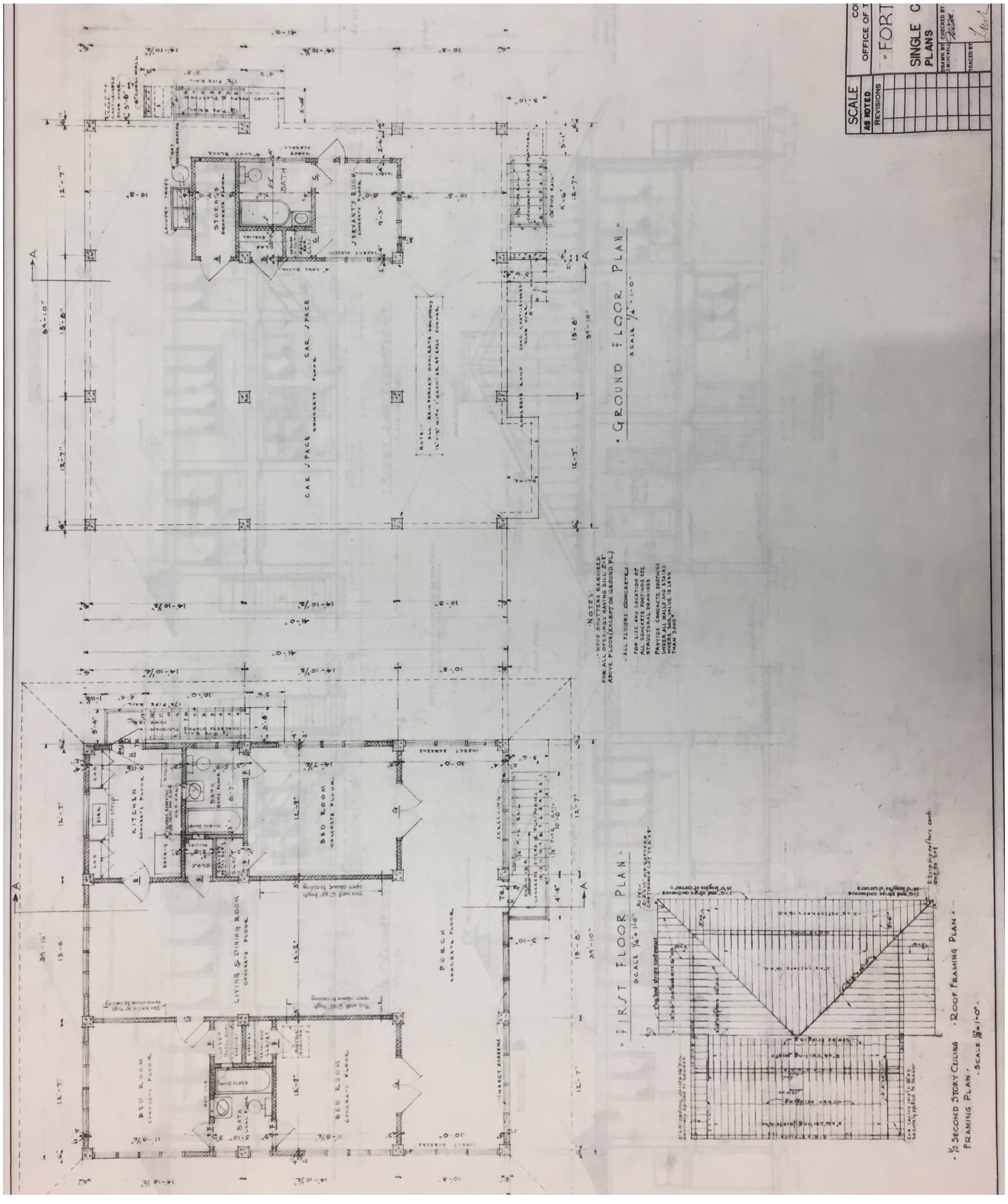

Figure B.42: *Single CO Quarters Type 3, Plans, Fort Sherman, PCZ. Image courtesy of the National Archives and Records Administration.*

QUARRY HEIGHTS | ANCON

Quarry Heights is named so because it was built on the terraces of the former quarry into Ancon Hill that was used during the construction of the Canal. Ancon Hill is at the Pacific Entrance of the Canal on the east side. It is flanked by Panama City, Albrook Air Force Station, and Forts Amador and Davis. The area was designated as a military reservation not long after the Canal was built, and it was used as the Headquarters for the Panama Canal Department during the period in which it had control of the Canal.

Commanding Officer's Quarters

Location: Quarry Heights | Ancon
Date of Photographs: 1916

Figure B.43: *Commanding Officer's Quarters, Perspective, Quarry Heights, PCZ. Image courtesy of the National Archives and Records Administration.*

This building was used as the Commanding Officer's Quarters when Quarry Heights became a U.S. Army post after the completion of the Canal. When the canal was completed and military installations were being established throughout the canal zone, many of the first posts did not have housing built as new construction but instead reused wood frame housing that was erected during the building face of the canal. Quarry Heights was one of these posts where the earlier housing was moved to and reassembled. This building is likely one of those that was moved, reflecting both French colonial influences from their time spent trying to construct a canal, as well as American influences.. These structures differ slightly from the later aesthetic of Canal Zone housing that truly emerged as a distinct firm later in the 1920s and 1930s. The long screened in porches and low-pitched hipped roofs with wide overhanging eaves are just some of the elements that continued to be used in Canal Zone architecture in the following decades.

These photographs are part of a larger collection located in the National Archives in College Park Maryland. See References for further details.

Officers' Quarters

Location: Quarry Heights | Ancon
Date of Drawings: 1915
Date of Photographs: 1990s

Figure B.44: *Officers' Quarters, Perspective, Quarry Heights, PCZ. Image courtesy of the Library of Congress.*

This group of buildings located at the former Quarry Heights military reservation was used by the United States as Officers' Quarters. On the original plans, however, the title of the drawings state that the buildings are "Staff Quarters" rather than housing for Officer's. Whether they were intended for this use, or Staff was just a synonym for Officer's is unclear. The buildings represent relatively early housing construction in the Canal Zone. This design was likely intended to be of permanent construction due to its location at Quarry Heights. The buildings are nearly square in plan, constructed of wood frame supported by a concrete footing and wood post foundation that raises the buildings slightly above ground.

These images and drawings are part of a larger collection of photographs for Quarry Heights Officers' Quarters. They were accessed through the online catalog for the Library of Congress.

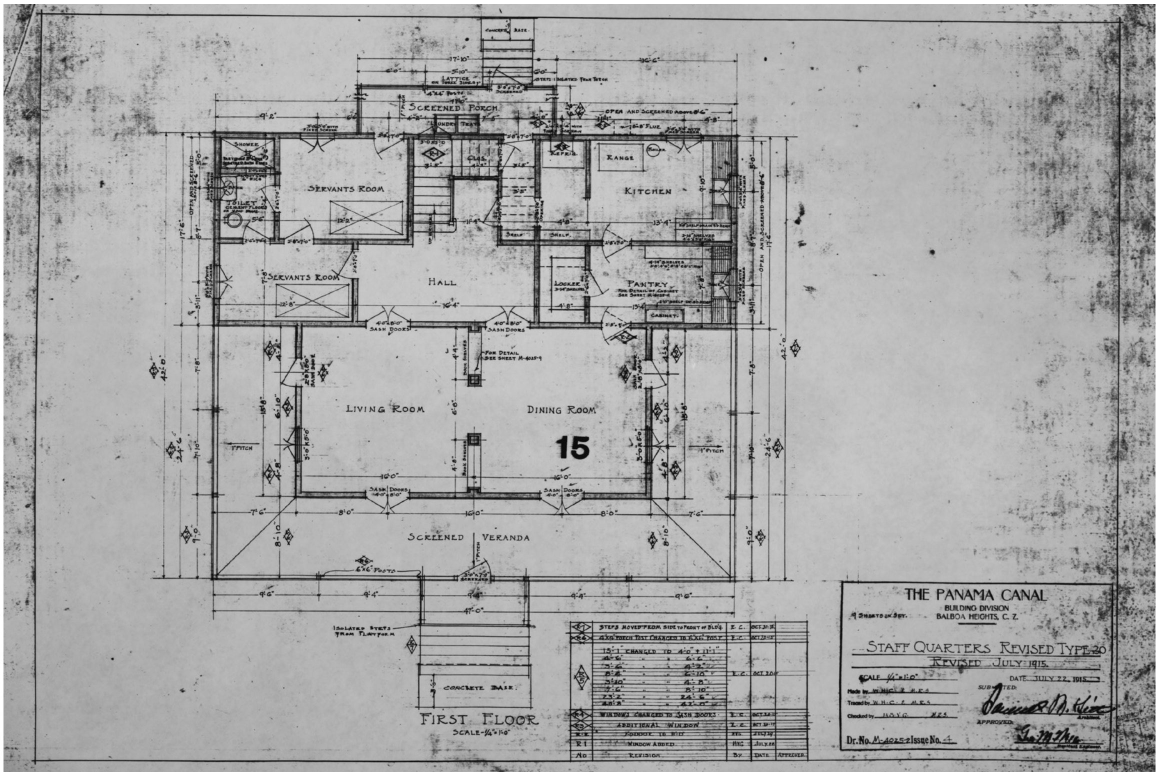

Figure B.45: *Officers' Quarters, First Floor Plan, Quarry Heights, PCZ. Image courtesy of the Library of Congress.*

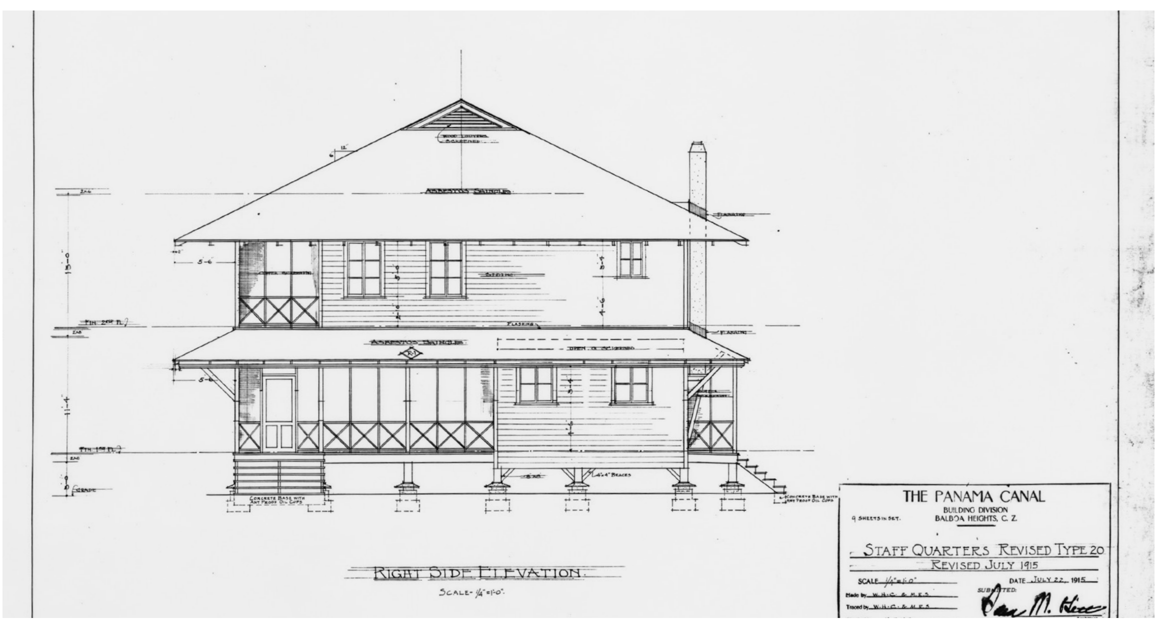

Figure B.46: *Officers' Quarters, Side Elevation - Drawing, Quarry Heights, PCZ. Image courtesy of the Library of Congress.*

The images on these pages show the Officers' Quarters at Quarry Heights in greater detail. the image below shows that the buildings were designed with a degree of sophistication for the Officers' due to their rank. Stylistic elements such as this would not be standard in an enlisted men's barracks. The photograph at top-right shows one of the bedrooms. The wall studs are left exposed on the interior in order to prevent rats from breeding in the walls. The image below shows one of the side elevations; it is the same elevation as that shown in one of the architectural drawings on the previous page. Note that the quarters in the photograph has an extra window on the second floor that is not shown in the architectural drawing.

Figure B.47: *Officers' Quarters, Interior Stair, Quarry Heights, PCZ. Image courtesy of the Library of Congress.*

Figure B.48: *Officers' Quarters, Exposed Studs, Quarry Heights, PCZ. Image courtesy of the Library of Congress.*

Figure B.49: *Officers' Quarters, Side Elevation - Photograph, Quarry Heights, PCZ. Image courtesy of the Library of Congress.*

Quarters No. 311

Location: Quarry Heights | Ancon
Date of Drawings: 1964

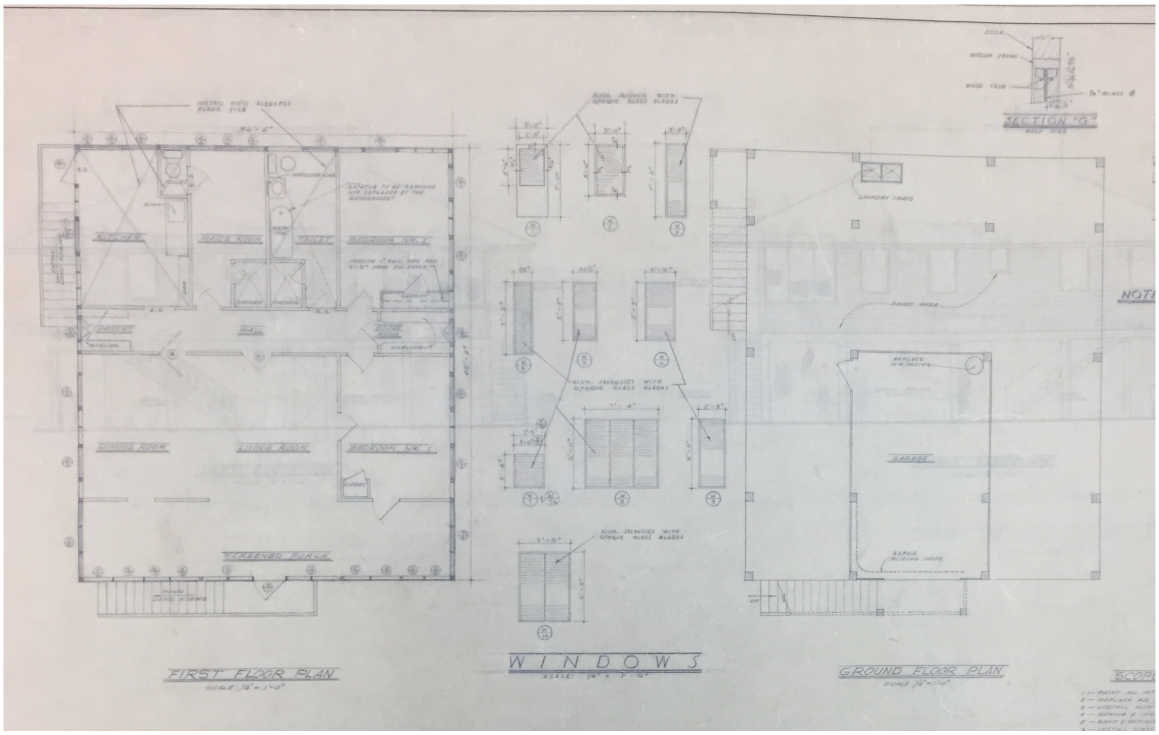

Figure B.50: *Quarters No. 311, Plans, Quarry Heights, PCZ. Image courtesy of the National Archives and Records Administration.*

The drawings et for these quarters is dated 1964. The building itself, however, was likely constructed at an earlier date. This is evident from the title of the drawings: "Improvements to Quarters 311." This was later in the period during which many of the early quarters were being updated with air conditioning and modern mechanical systems. Construction of the building calls for concrete construction on the ground floor and wood frame on the top. Casement windows, overhanging eaves, and pent roof with ridge vents are all present in this design.

These architectural drawings are part of a larger collection located in the National Archives in College Park Maryland. See References for further details.

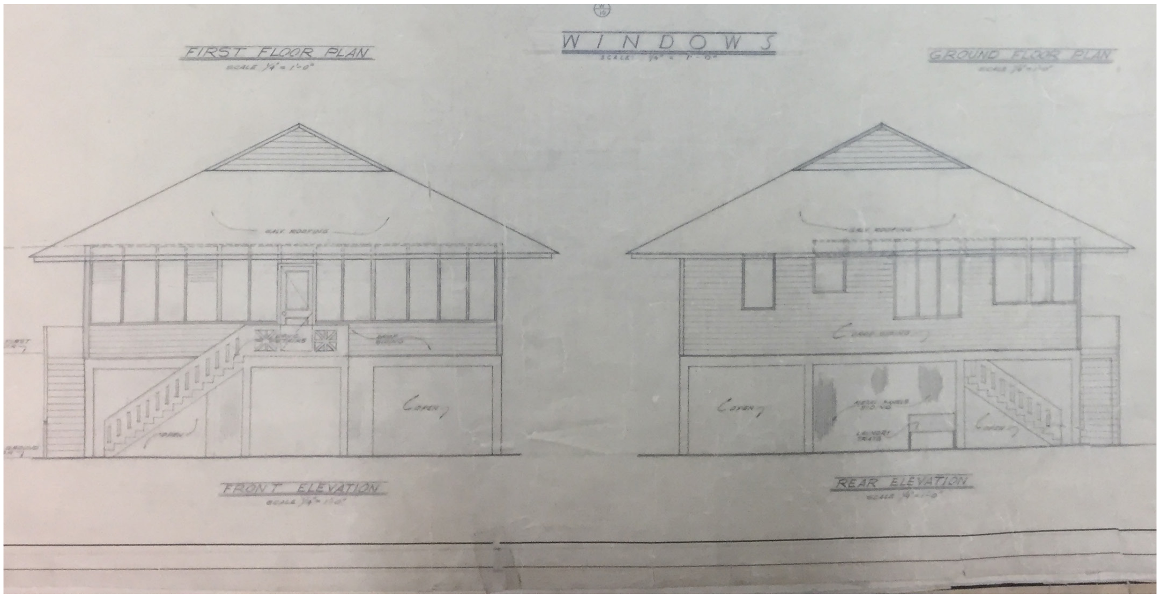

__Figure B.51:__ Quarters No. 311, Front and Rear Elevations, Quarry Heights, PCZ. Image courtesy of the National Archives and Records Administration.

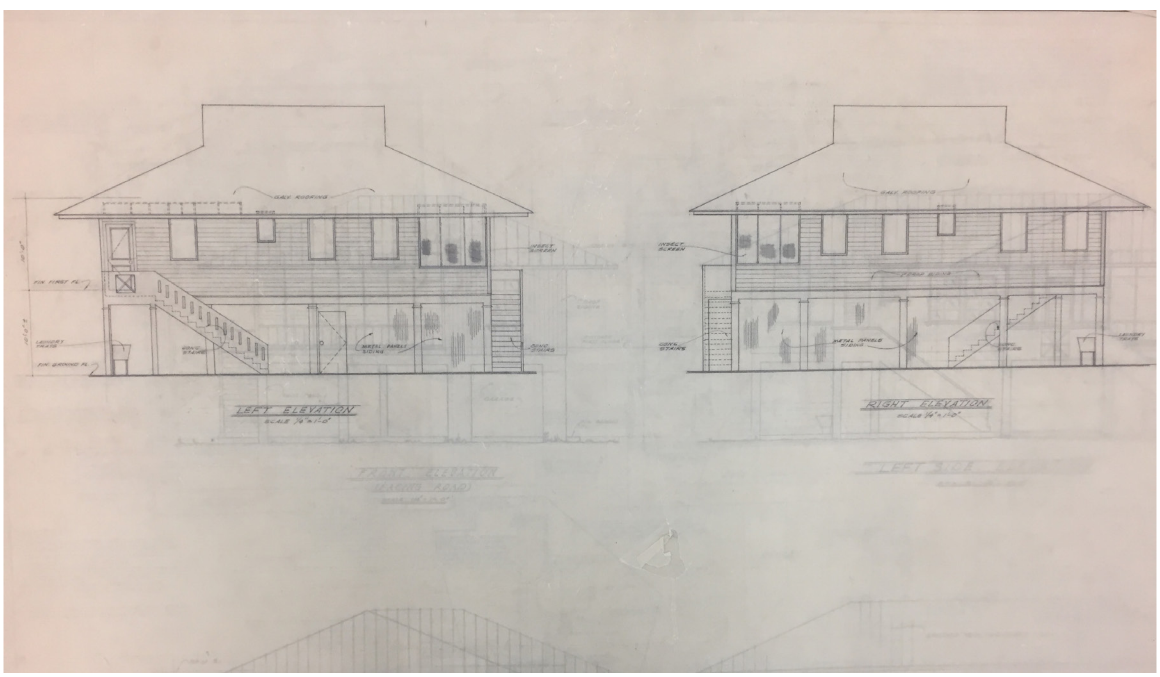

__Figure B.52:__ Quarters No. 311, Side Elevations, Quarry Heights, PCZ. Image courtesy of the National Archives and Records Administration.

MOUNT HOPE

Mount Hope was a large industrial division area with residential sections to house workers. It is located at the Atlantic at the Atlantic entrance to the Panama Canal. Mount Hope is also the location of a large cemetery where workers who died while working to construct the Panama Railroad during the nineteenth century are interred. Mount Hope was the main supply location for Canal Zone Commissaries.[163]

[163] Crouch, *Architecture of the Panama Canal Zone*, 119.

Single CO Quarters Type 7

Location: Mount Hope
Date of Drawings: 1939

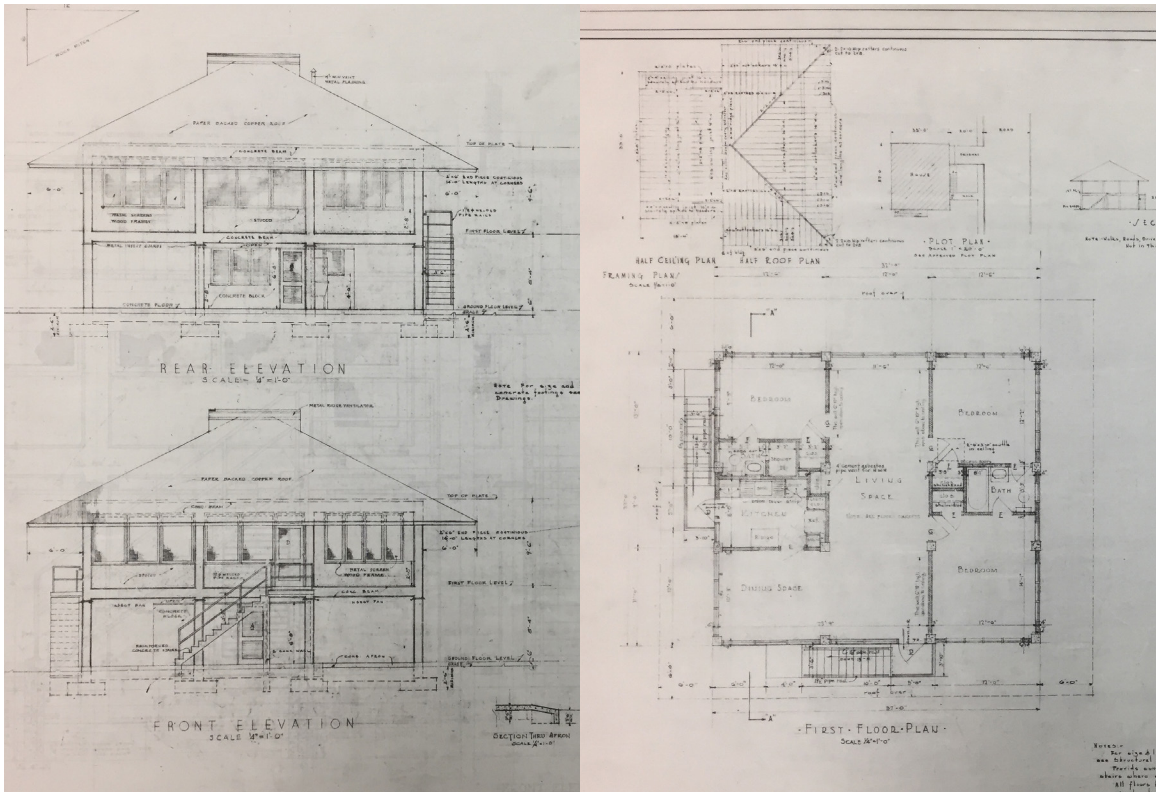

Figure B.53: *Single CO Quarters Type 7, Elevations and Plans, Mount Hope, PCZ. Image courtesy of the National Archives and Records Administration.*

This design is very similar to that of the Single CO Quarters Type 3 located at Fort Sherman. Both the plans for Type 7 shown here and those for Type 3 at Fort Sherman are likely different forms of one original design. For many of the standardized plans, a building design would be drawn up for use, and then various types of that set of plans were created in order to allow for some variation without having to design a completely new building design. Budget costs for design and construction of military buildings were an issue during the late nineteenth and early twentieth century, and this was likely done to cut down on design costs. An additional set of these plans was found later during research, but no location was listed on the drawings. This is further evidence that the plans are a standard set that was used where it was needed.

These architectural drawings are part of a larger collection located in the National Archives in College Park Maryland. See References for further details.

UNSPECIFIED

The architectural drawings for the four building designs on the following pages have no location listed on them. This prevents determining where within the Canal Zone they are located. Due to the fact that no location is indicated, it is very likely that these drawings are all standardized housing designs for use in the Panama Canal Zone. These designs were likely used throughout the Canal Zone at various military installations. The corresponding type associated with each design indicates its number in association with the original standardized design from which all following types were derived.

Field Officer's Quarters Type 1

Location: Unspecified
Date of Drawings: 1939

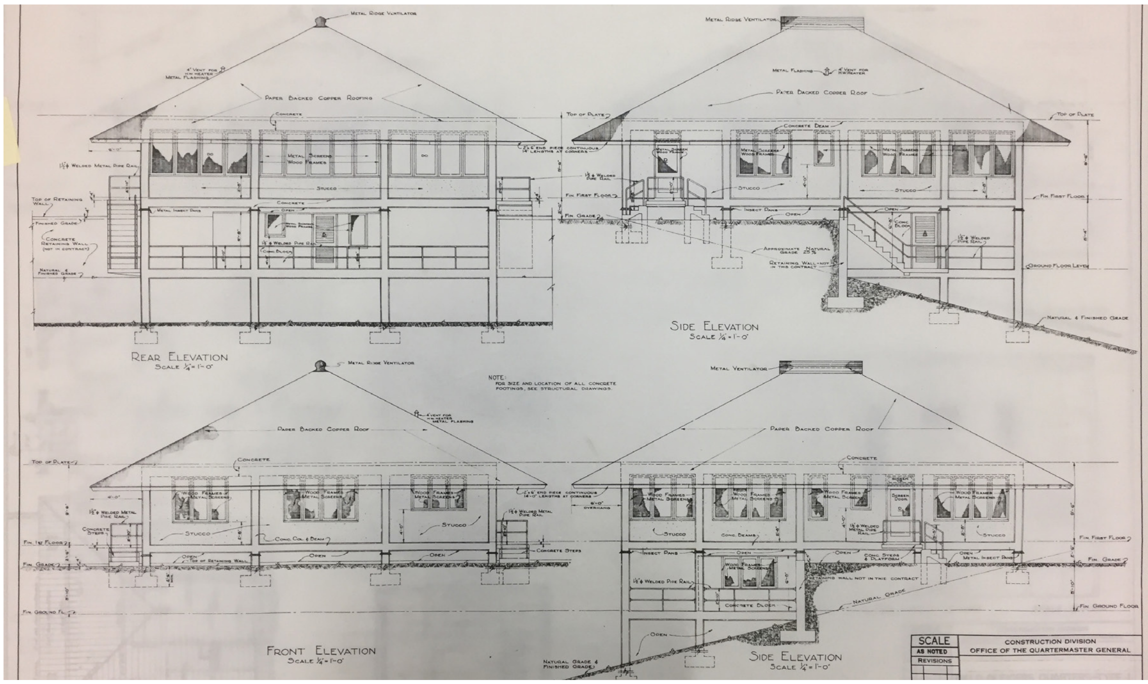

Figure B.54: *Field Officer's Quarters Type 1, Elevations, Unspecified. Image courtesy of the National Archives and Records Administration.*

This design is interesting since the drawings indicate that it is to be built into a hill or terrace. This design is likely a single part of a large group of housing designs completed in 1939. The three housing designs on the following pages are also a part of this larger group of designs, as is the design for the Single CO Quarters Type 3 located at Fort Sherman.

These architectural drawings are part of a larger collection located in the National Archives in College Park Maryland. See References for further details.

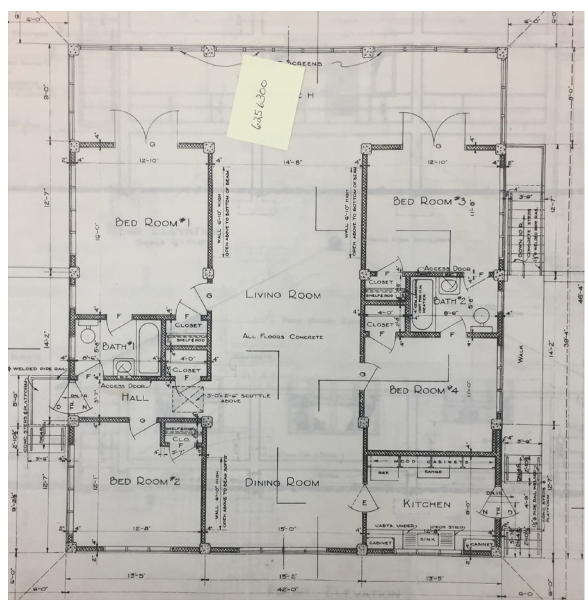

Figure B.55: *Field Officer's Quarters Type 1, Floor Plan, Unspecified. Image courtesy of the National Archives and Records Administration.*

Single Field Officer's Quarters Type 2

Location: Unspecified
Date of Drawings: 1939

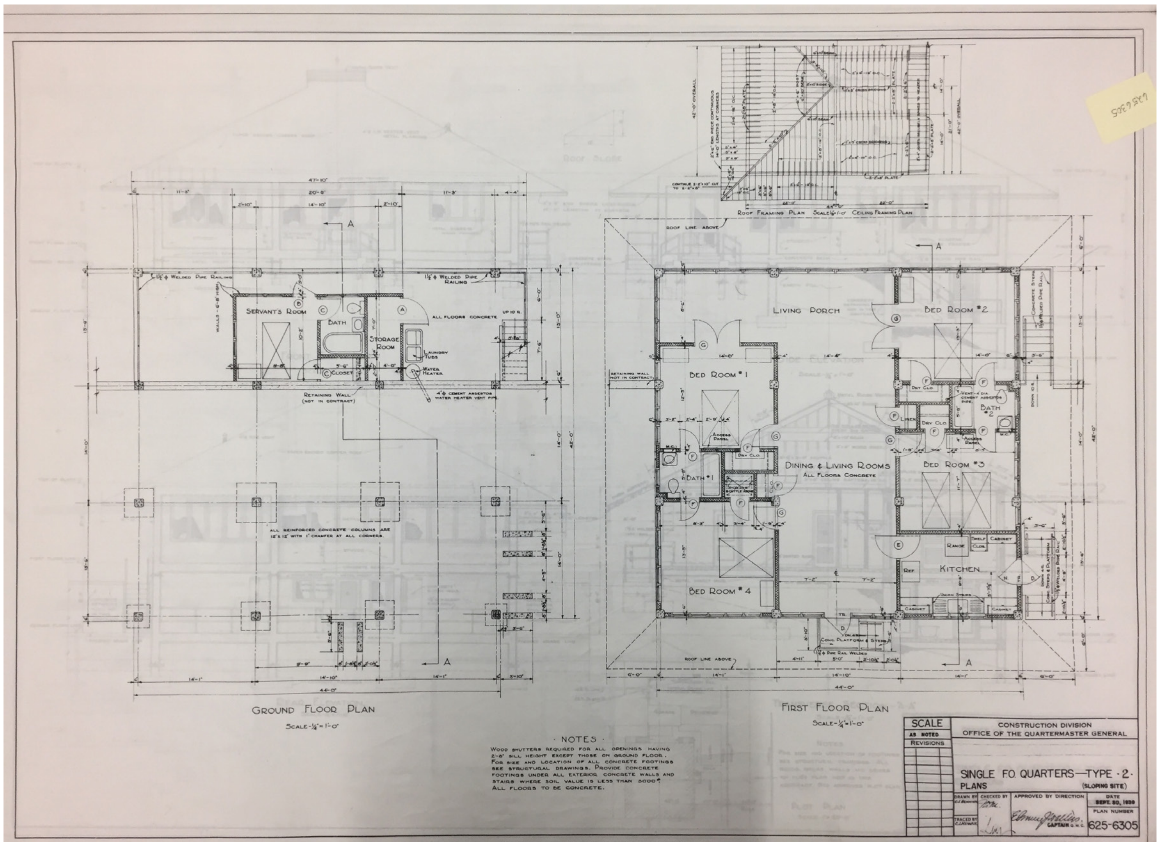

Figure B.56: *Single Field Officer's Quarters Type 2, Floor Plan, Unspecified. Image courtesy of the National Archives and Records Administration.*

The above image shows the only drawing identified as belonging to the Single Field Officer's Quarters Type 2. While there are no drawings of the elevations, the size and layout of the plan indicate that the exterior could be similar to that of the design for Field Officer's Quarters Type 1 shown on the previous page. The first floor plans for both are largely identical, the only exceptions being the truncation of Bedroom #1 in the plan above, as well as the lack of a full length porch that is present in the design for FO Quarters Type 1.

These architectural drawings are part of a larger collection located in the National Archives in College Park Maryland. See References for further details.

Single Field Officer's Quarters Type 5

Location: Unspecified
Date of Drawings: 1939

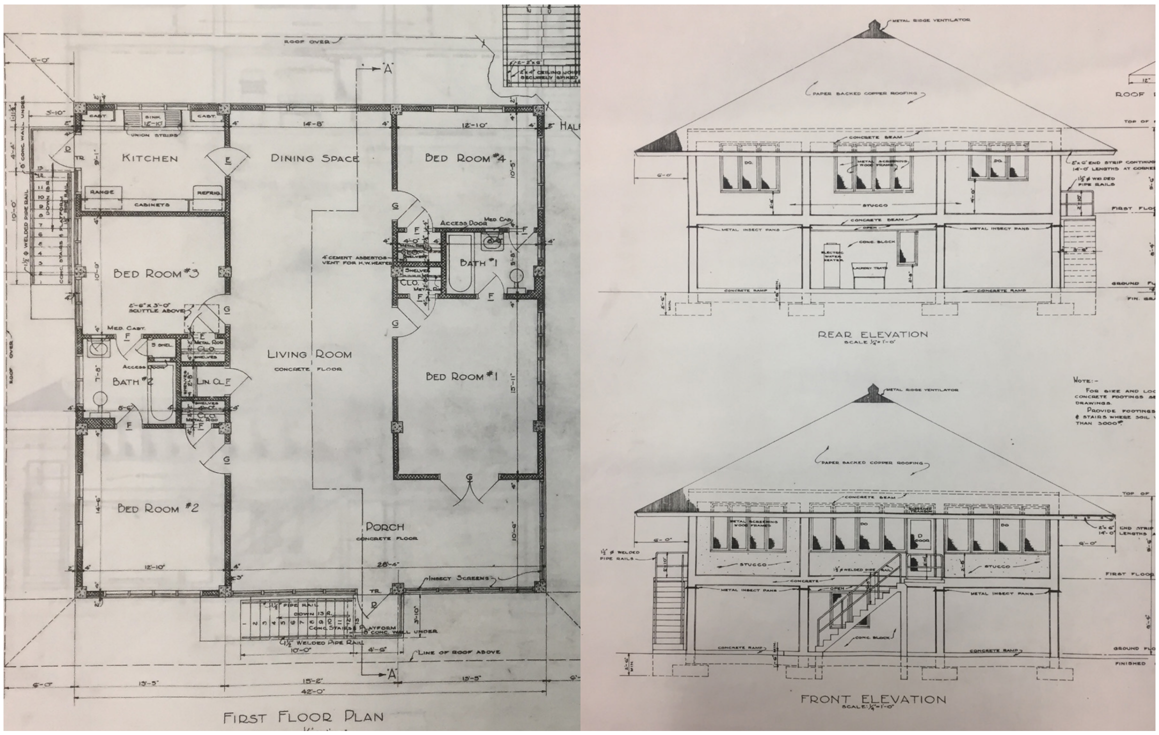

Figure B.57: *Single Field Officer's Quarters Type 5, Elevations and Floor Plan, Unspecified. Image courtesy of the National Archives and Records Administration.*

The first floor plan above is similar to the plan for the Type 2 Quarters on the opposite page. Elevations for the design are also very similar to preceding examples which include the Field Officer's Quarters Type 1 and the CO Quarter's Type 3 at Fort Sherman. It can be inferred that the elevations shown above are likely very similar to the elevations that were design for the Type 2 Quarters seen opposite. The floor plans and elevations for all of these buildings are very similar, and likely followed one design as a standard.

These architectural drawings are part of a larger collection located in the National Archives in College Park Maryland. See References for further details.

Single NCO Quarters Type 4

Location: Unspecified
Date of Drawings: 1939

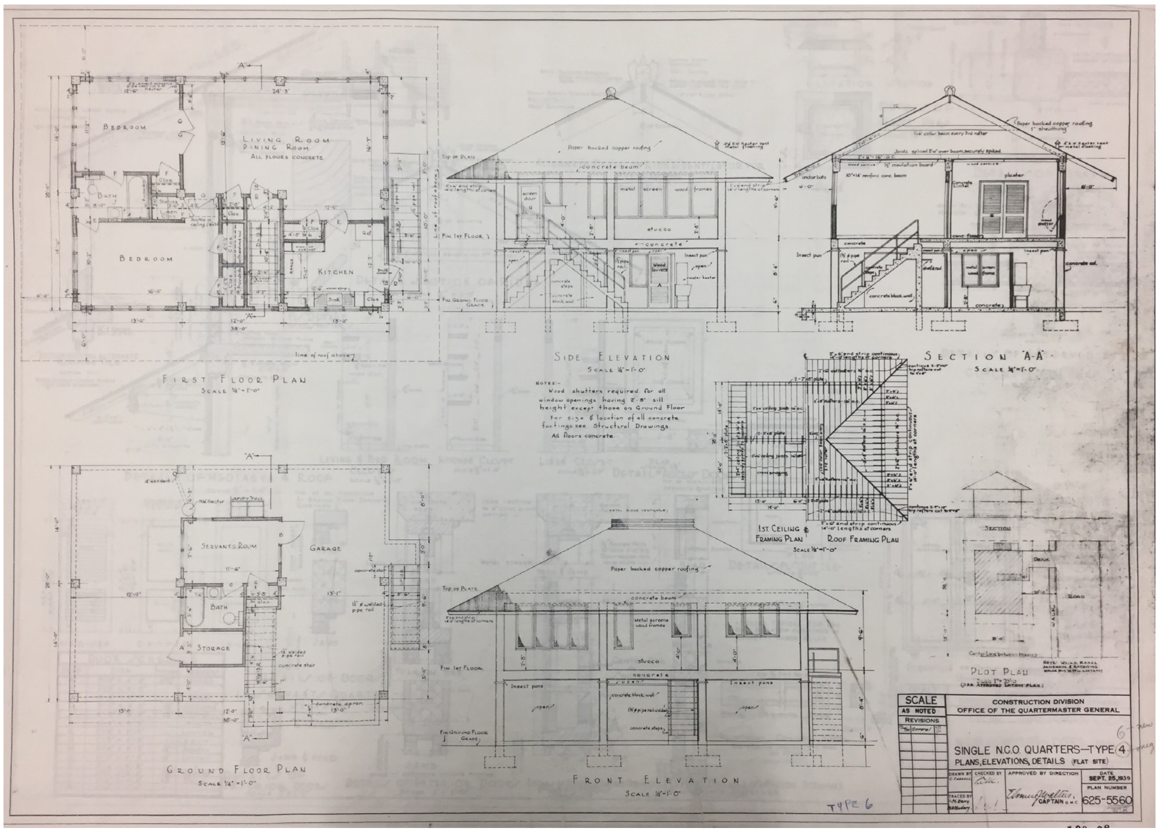

__Figure B.58:__ Single NCO Quarters Type 4, Elevation, Plans, and Section, Unspecified. Image courtesy of the National Archives and Records Administration.

The design for the quarters above differs slightly from the other three designs addressed in this section. Rather than being square in plan, these Type 4 quarters are clearly rectangular. The spatial layout and organization for the interior is also extremely different. No central corridor or living space exists in this design. Instead it seems that each of the four primary rooms in the building occupy their own corner of the house. The bedrooms and kitchen all open into the living room which is the largest room in the house. However, here it does not serve as the central space in the house. The exterior remains similar to the others; it is also constructed of concrete, which is standard for these designs.

These architectural drawings are part of a larger collection located in the National Archives in College Park Maryland. See References for further details.

Appendix C:

Climate Consultant Design Guidelines for Adaptive Comfort

The following twenty design guidelines were produced by Climate Consultant in accordance with the parameters put forth following the Adaptive Comfort design strategy. The program uses climatic data for a specific local using the desired parameters in order to create design guidelines for building design that seek to maximize indoor comfort. The guidelines provided here are for Charleston, SC for the months of March through August in accordance with the parameters used in Chapter Seven.

Charleston, SC
Design Guidelines: Adaptive Comfort
March through August

1. Good natural ventilation can reduce or eliminate air conditioning in warm weather, if windows are well shaded and oriented to prevailing breezes.

2. To capture natural ventilation, wind direction can be changed up to 45 degrees toward the building by exterior wing walls and planting.

3. A long narrow building floor plan can help maximize cross ventilation in temperate and hot humid climates.

4. To facilitate cross ventilation, locate door and window openings on opposite sides of a building with larger openings facing up-wind if possible.

5. Screened porches and patios can provide passive comfort cooling by ventilation in warm weather and can prevent insect problems.

6. On hot days, ceiling fans or indoor air motion can make it seem cooler by 5 degrees F (2.8C) or more, thus less air conditioning is needed.

7. Use open plan interiors to promote natural cross-ventilation, or use louvered doors, or instead use jump ducts if privacy is needed.

8. To produce stack ventilation, even when wind speeds are low, maximize vertical height between air inlet and outlet (open stairwells, two story spaces, roof, etc.).

9. A whole-house fan or natural ventilation can store nighttime ‘coolth’ in high mass interior surfaces (night flushing), to reduce or eliminate air conditioning.

10. This is one of the more comfortable climates, so shade to prevent overheating, open breezes in the summer, and use passive solar gain in the winter.

11. Traditional passive homes in temperate climates used light weight construction with slab on grade and operable walls and shaded outdoor spaces.

12. Traditional passive homes in warm humid climates used high ceilings and tall operable (French) windows protected by deep overhangs and verandas.

13. Shaded outdoor buffer zones (porch, patio, lanai) oriented to the prevailing breezes can extend living and working areas in warm or humid weather.

14. Provide enough north glazing to balance daylighting and allow cross ventilation (about 5% of floor area).

15. Low pitched roofs with wide overhangs works well in temperate climates.

16. Use plant materials (bushes, trees, ivy-covered walls) especially on the west to minimize heat gain (if summer rains support native plant growth).

17. In wet climates well ventilated attics with pitched roofs work well to shed rain and can be extended to protect entries, porches, verandas, and outdoor work areas.

18. If soil is moist, raise the building high above ground to minimize dampness and maximize natural ventilation underneath the building.

19. Minimize or eliminate west facing glazing to reduce summer and fall afternoon heat gain.

20. Window overhangs (designed for this latitude) or operable sunshades (awnings that extend in the summer) can reduce or eliminate air conditioning.

Appendix D:

Supplemental Drawings and Images

The following images are screenshots of the SketchUp models created for use in the Flow Design simulations to analyze natural airflow through buildings. Each model was created using SketchUp. Both Panama House designs, as well as the control buildings, are included in this appendix. Elevation and perspective images are included for each building.

Panama House | Initial Design
Construction Date: 1937
Front and Rear Elevations

Figure D.1: *Panama House Type 1, Front Elevation. Screenshot in SketchUp by author.*

Figure D.2: *Panama House Type 1, Rear Elevation. Screenshot in SketchUp by author.*

Panama House | Initial Design
Construction Date: 1937
Side Elevations

Figure D.3: *Panama House Type 1, Left Elevation. Screenshot in SketchUp by author.*

Figure D.4: *Panama House Type 1, Right Elevation. Screenshot in SketchUp by author.*

Panama House | Initial Design
Construction Date: 1937
Perspective Images

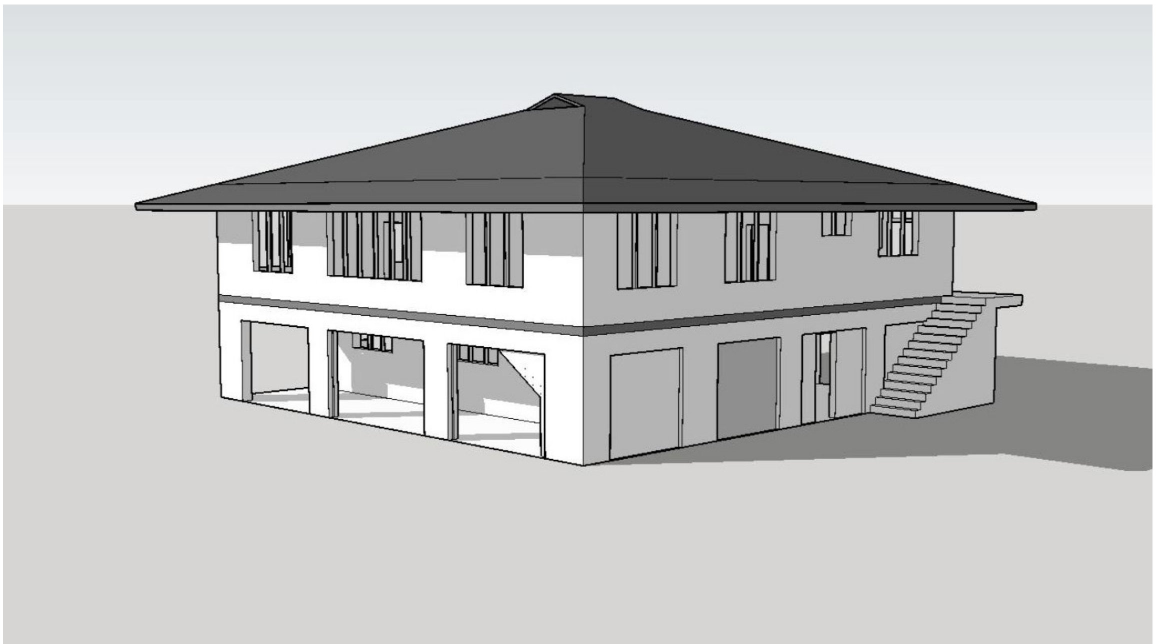

Figure D.5: *Panama House Type 1, Perspective Looking Southwest. Screenshot in SketchUp by author.*

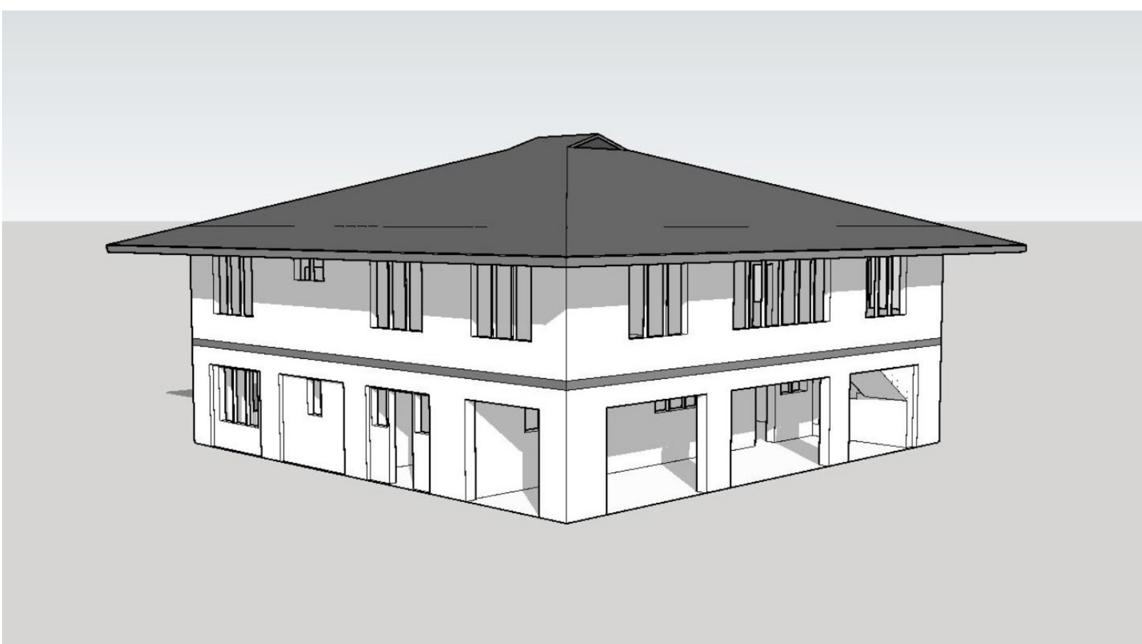

Figure D.6: *Panama House Type 1, Perspective Looking Northwest. Screenshot in SketchUp by author.*

Panama House | Initial Design
Construction Date: 1937
Perspective Images

Figure D.7: *Panama House Type 1, Perspective Looking Northeast. Screenshot in SketchUp by author.*

Figure D.8: *Panama House Type 1, Perspective Looking Southeast. Screenshot in SketchUp by author.*

Panama House | Design II
Construction Date: 1941
Front and Rear Elevations

Figure D.9: *Panama House Type II, Front Elevation. Screenshot in SketchUp by author.*

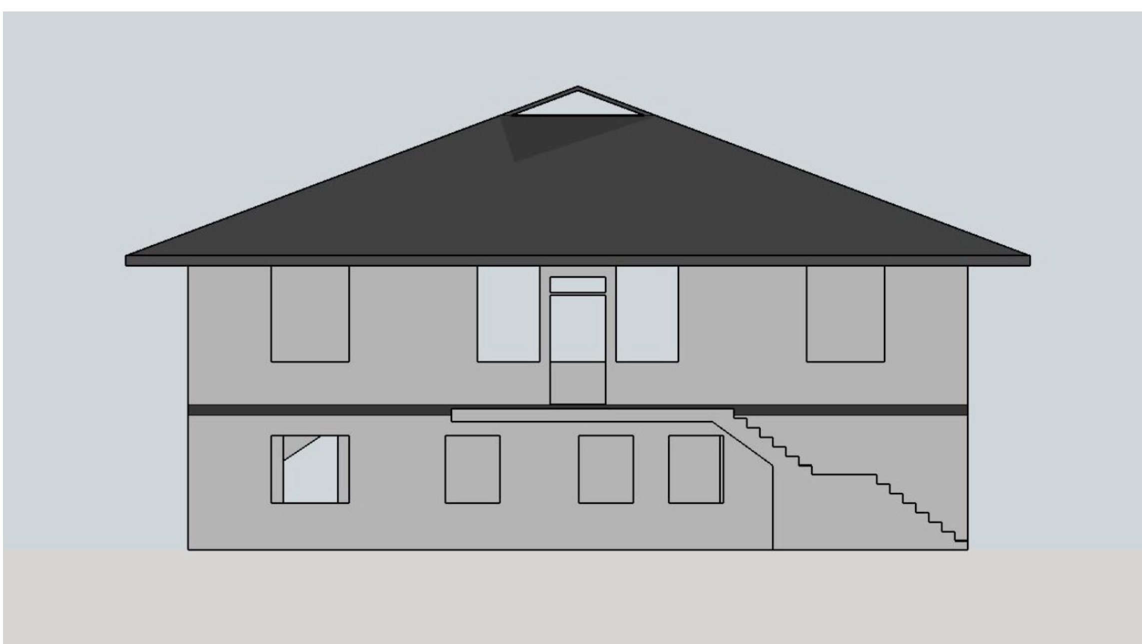

Figure D.10: *Panama House Type 1I, Rear Elevation. Screenshot in SketchUp by author.*

Panama House | Design II
Construction Date: 1941
Side Elevations

Figure D.11: *Panama House Type II, Left Elevation. Screenshot in SketchUp by author.*

Figure D.12: *Panama House Type II, Right Elevation. Screenshot in SketchUp by author.*

Panama House | Design II
Construction Date: 1941
Perspective Images

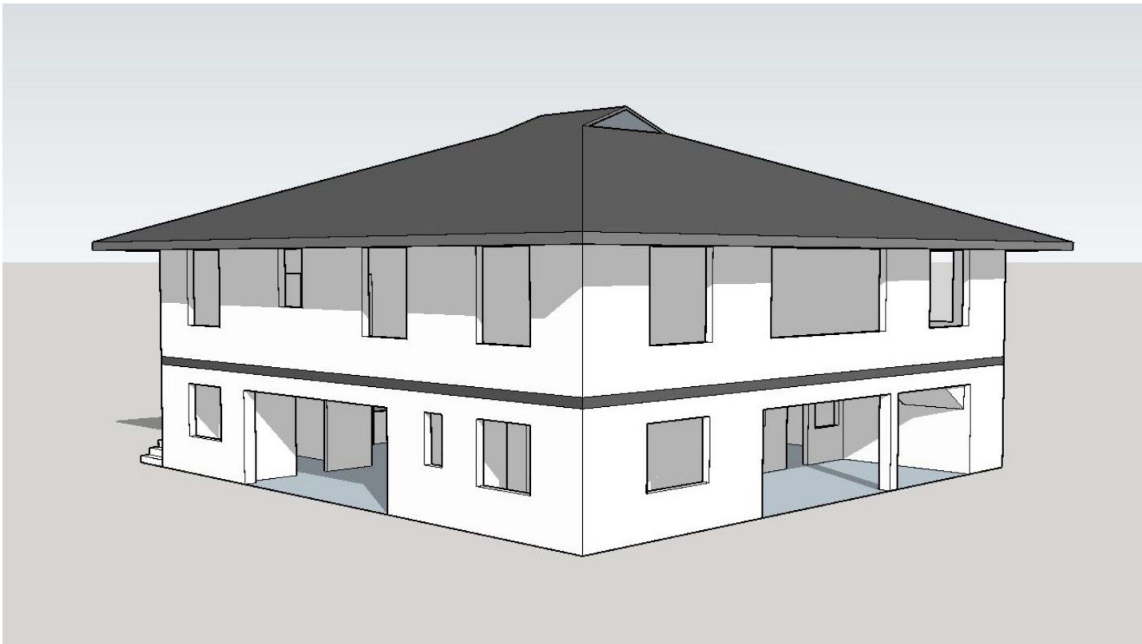

Figure D.13: *Panama House Type II, Perspective Looking Southwest. Screenshot in SketchUp by author.*

Figure D.14: *Panama House Type II, Perspective Looking Northwest. Screenshot in SketchUp by author.*

Panama House | Design II
Construction Date: 1941
Perspective Images

Figure D.15: *Panama House Type 1, Perspective Looking Northeast. Screenshot in SketchUp by author.*

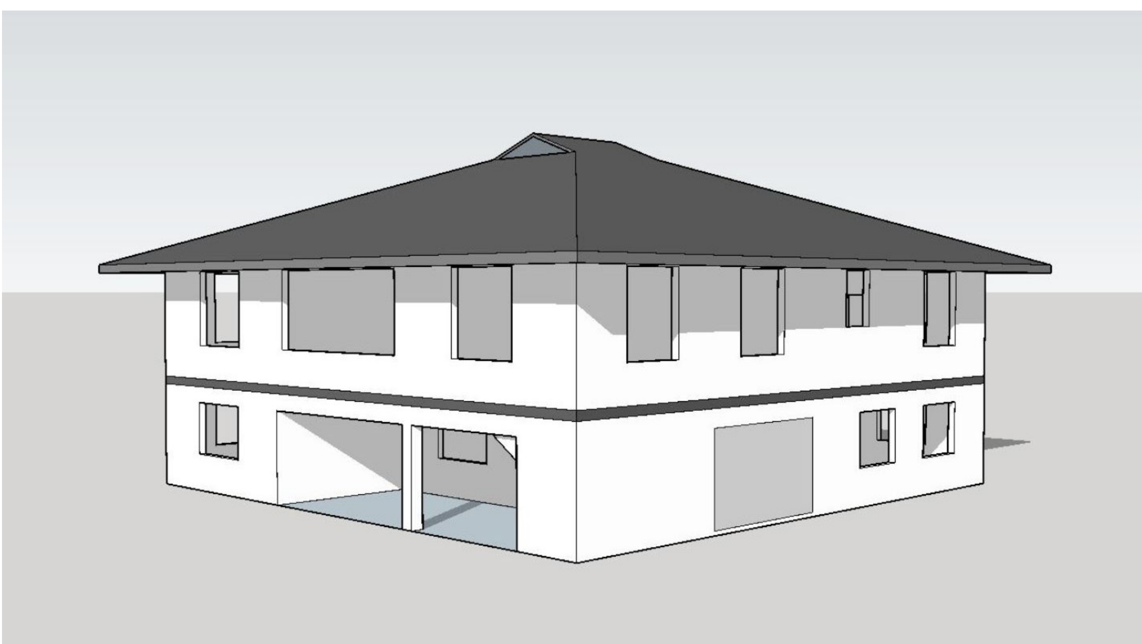

Figure D.16: *Panama House Type 1, Perspective Looking Southeast. Screenshot in SketchUp by author.*

Quarters X | Control Group
Construction Date: 1943
Front and Rear Elevations

Figure D.17: *Quarters X, Front Elevation. Screenshot in SketchUp by author.*

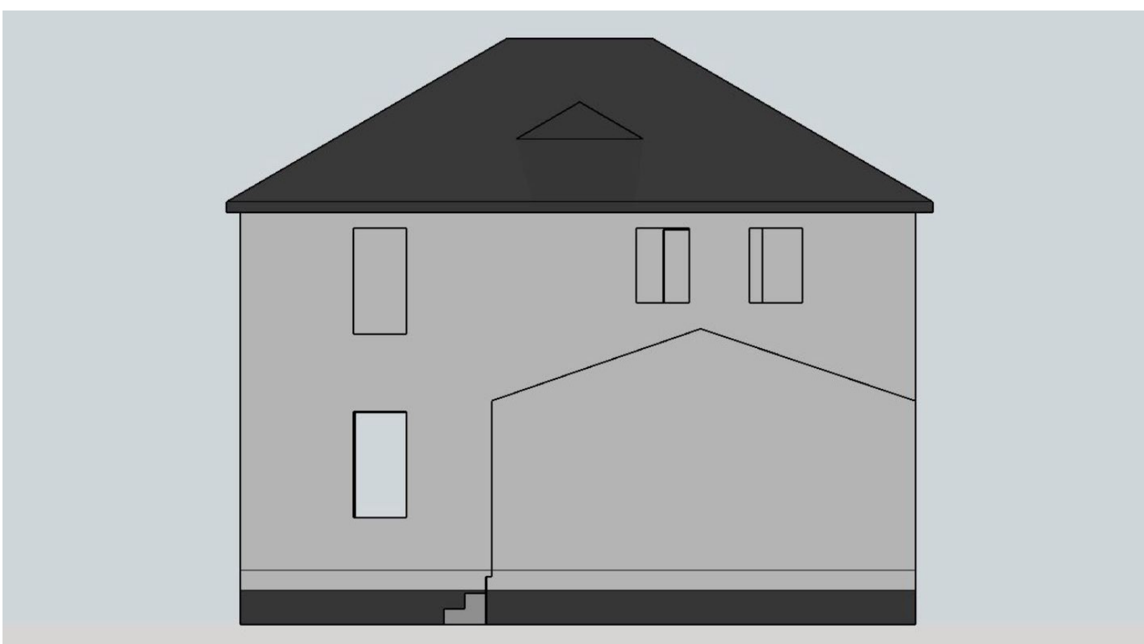

Figure D.18: *Quarters X, Rear Elevation. Screenshot in SketchUp by author.*

Quarters X | Control Group
Construction Date: 1943
Side Elevations

Figure D.19: *Quarters X, Left Elevation. Screenshot in SketchUp by author.*

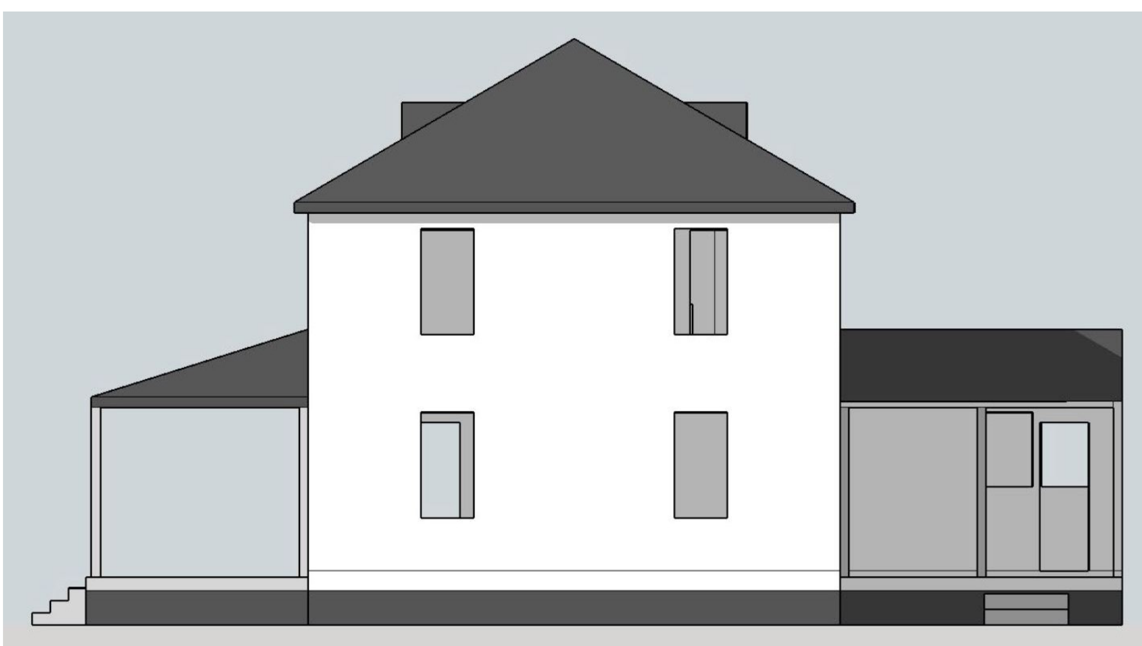

Figure D.20: *Quarters X, Right Elevation. Screenshot in SketchUp by author.*

Quarters X | Control Group
Construction Date: 1943
Side Elevations

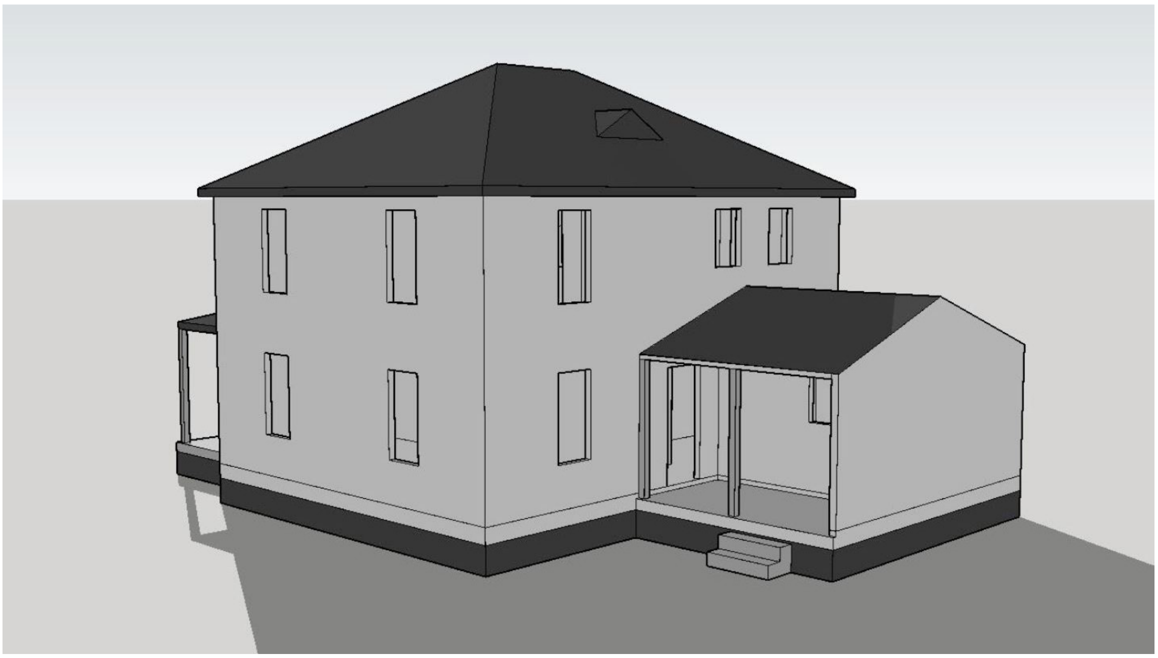

Figure D.21: *Quarters X, Perspective Looking Southwest. Screenshot in SketchUp by author.*

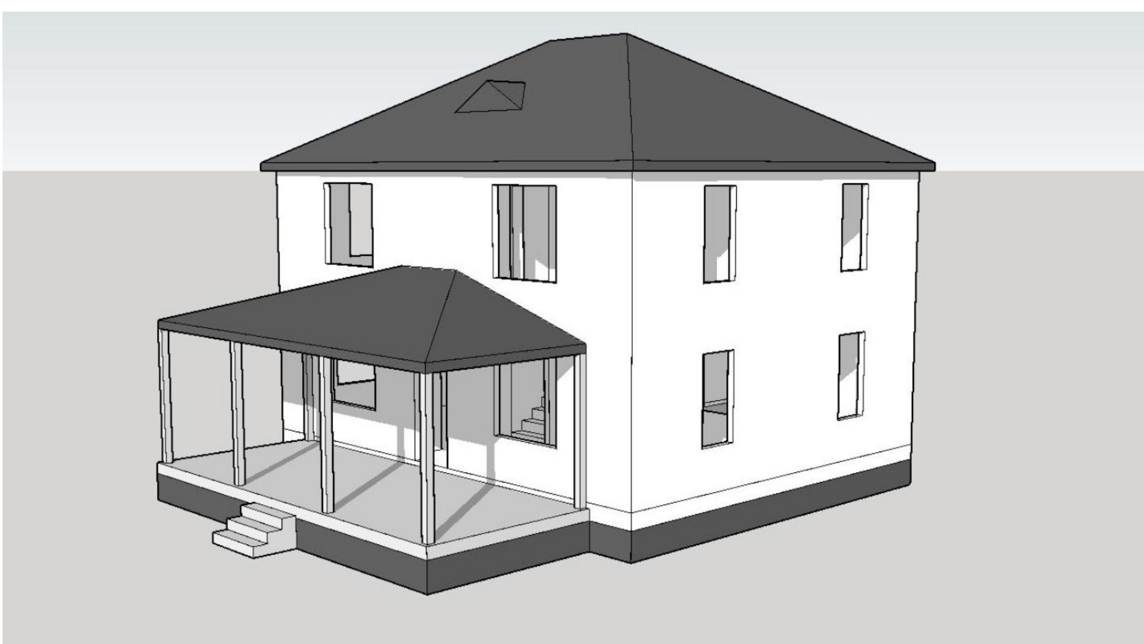

Figure D.22: *Quarters X, Perspective Looking Northwest. Screenshot in SketchUp by author.*

Quarters X | Control Group
Construction Date: 1943
Side Elevations

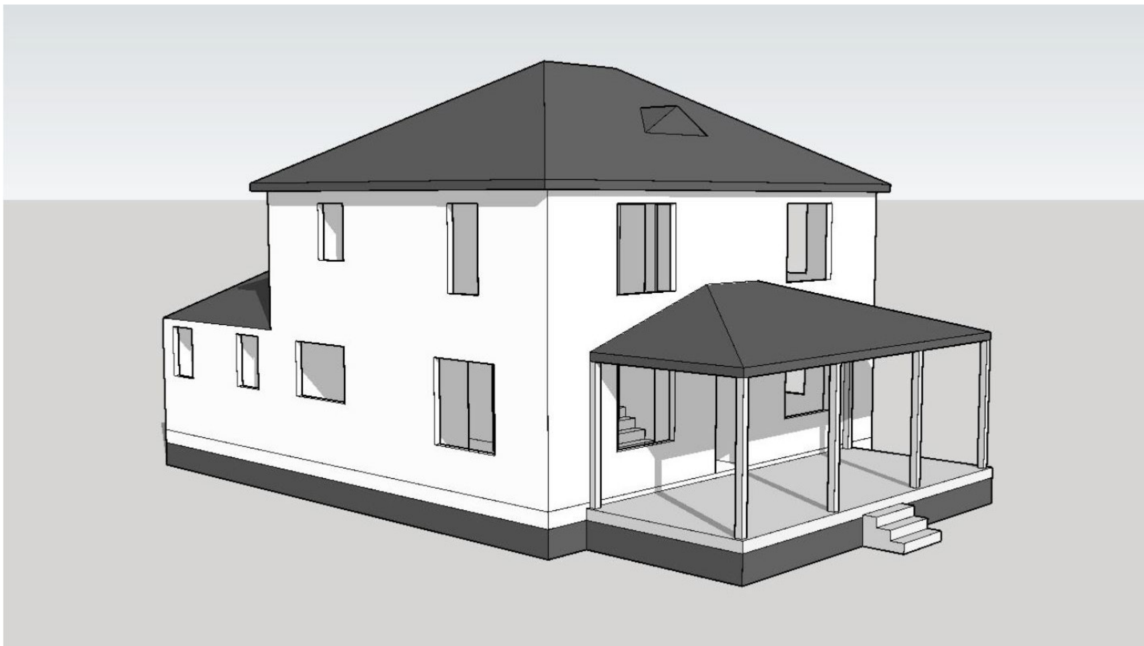

Figure D.23: *Quarters X, Perspective Looking Northeast. Screenshot in SketchUp by author.*

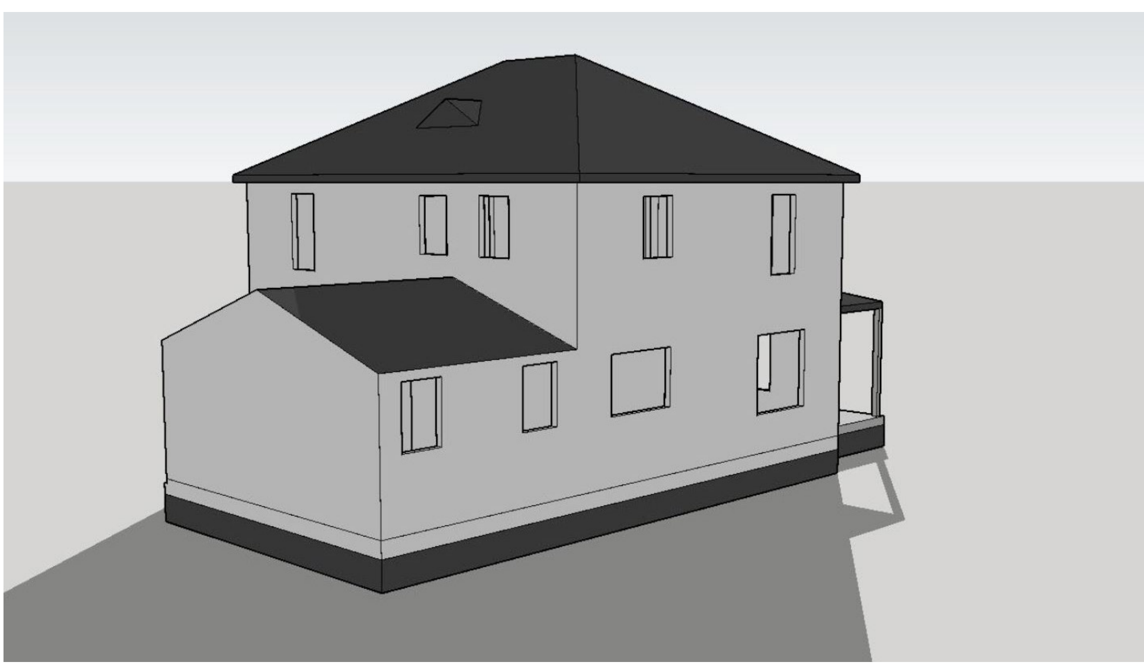

Figure D.24: *Quarters X, Perspective Looking Southeast. Screenshot in SketchUp by author.*

Quarters Y | Control Group
Construction Date: 1943
Front and Rear Elevations

Figure D.25: *Quarters Y, Front Elevation. Screenshot in SketchUp by author.*

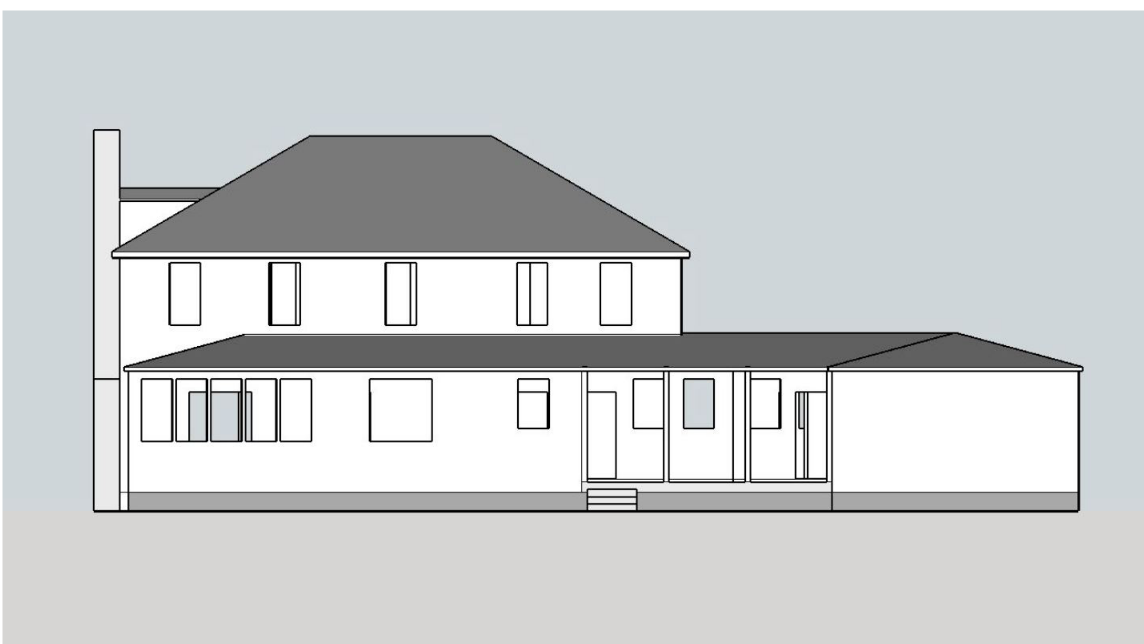

Figure D.26: *Quarters Y, Rear Elevation. Screenshot in SketchUp by author.*

Quarters Y | Control Group
Construction Date: 1943
Side Elevations

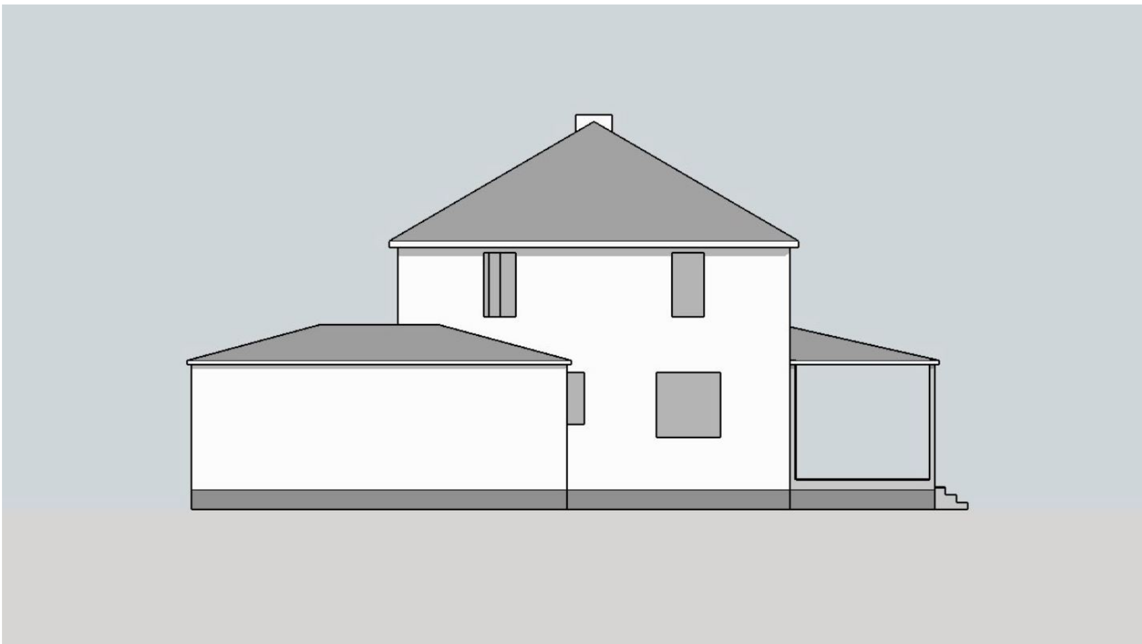

Figure D.27: *Quarters Y, Left Elevation. Screenshot in SketchUp by author.*

Figure D.28: *Quarters Y, Right Elevation. Screenshot in SketchUp by author.*

Quarters Y | Control Group
Construction Date: 1943
Side Elevations

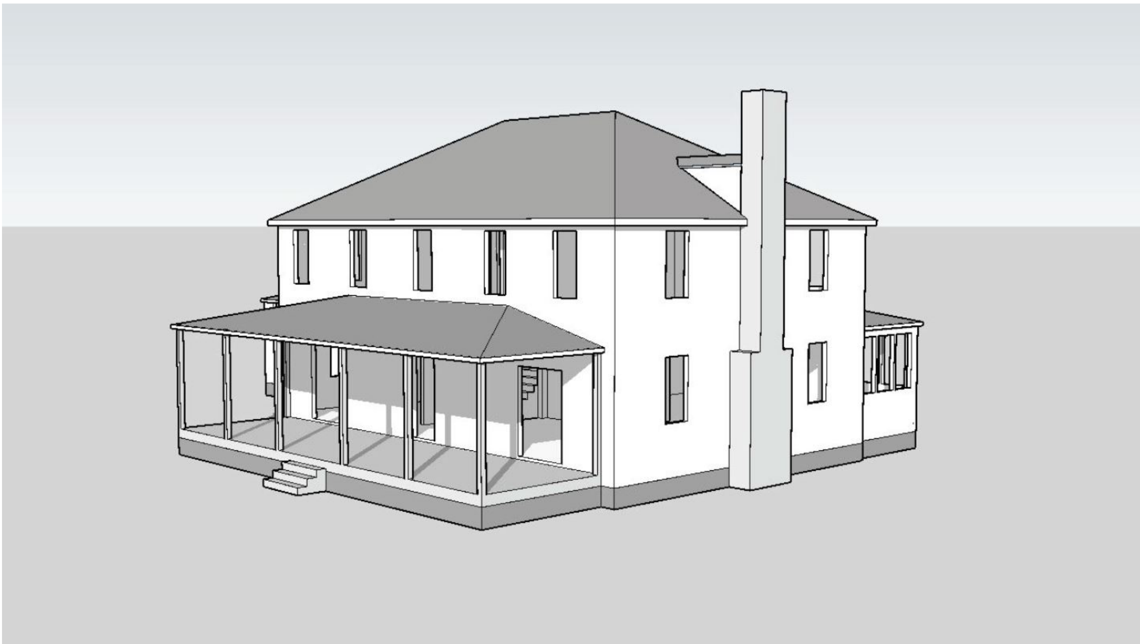

Figure D.29: *Quarters Y, Perspective Looking North. Screenshot in SketchUp by author.*

Figure D.30: *Quarters Y, Perspective Looking East. Screenshot in SketchUp by author.*

Quarters Y | Control Group
Construction Date: 1943
Side Elevations

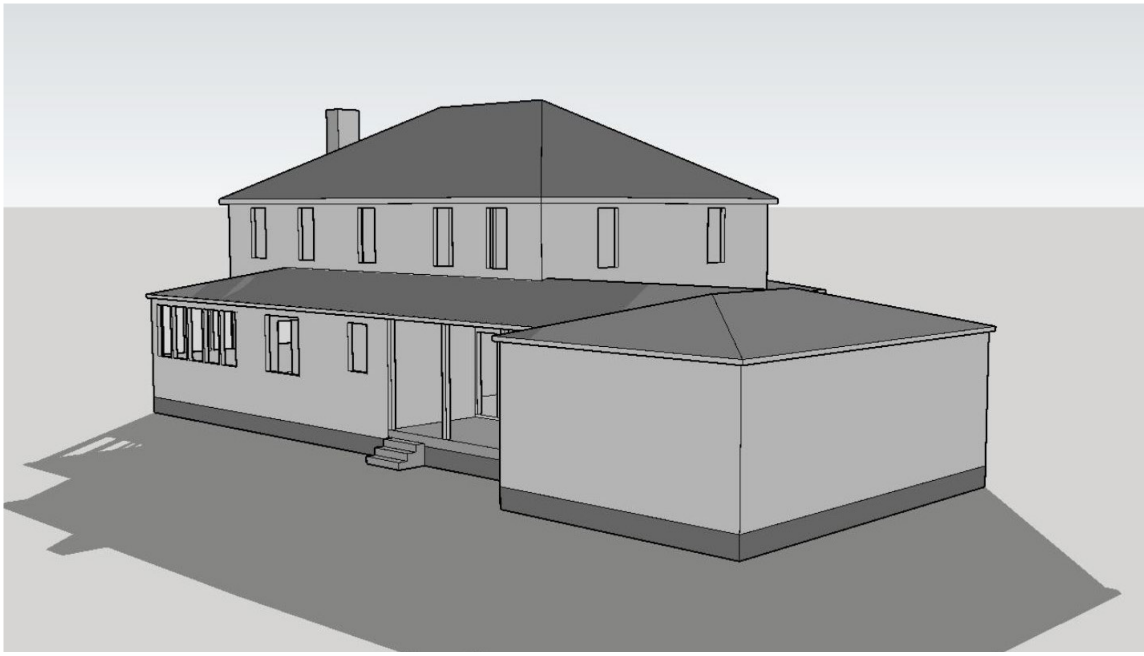

Figure D.31: *Quarters Y, Perspective Looking South. Screenshot in SketchUp by author.*

Figure D.32: *Quarters Y, Perspective Looking West. Screenshot in SketchUp by author.*

Appendix E:

Screenshots from Flow Design Simulations

The following images are screen-shots from the Flow Design simulations used to assess the ability of the designs of the Panama Houses and control buildings to naturally ventilate. These images are included in order to show each model within context of the simulation alongside relevant associated information such as air velocity and wind speed. Additional images that were not included in the analysis chapter can be found in this Appendix.

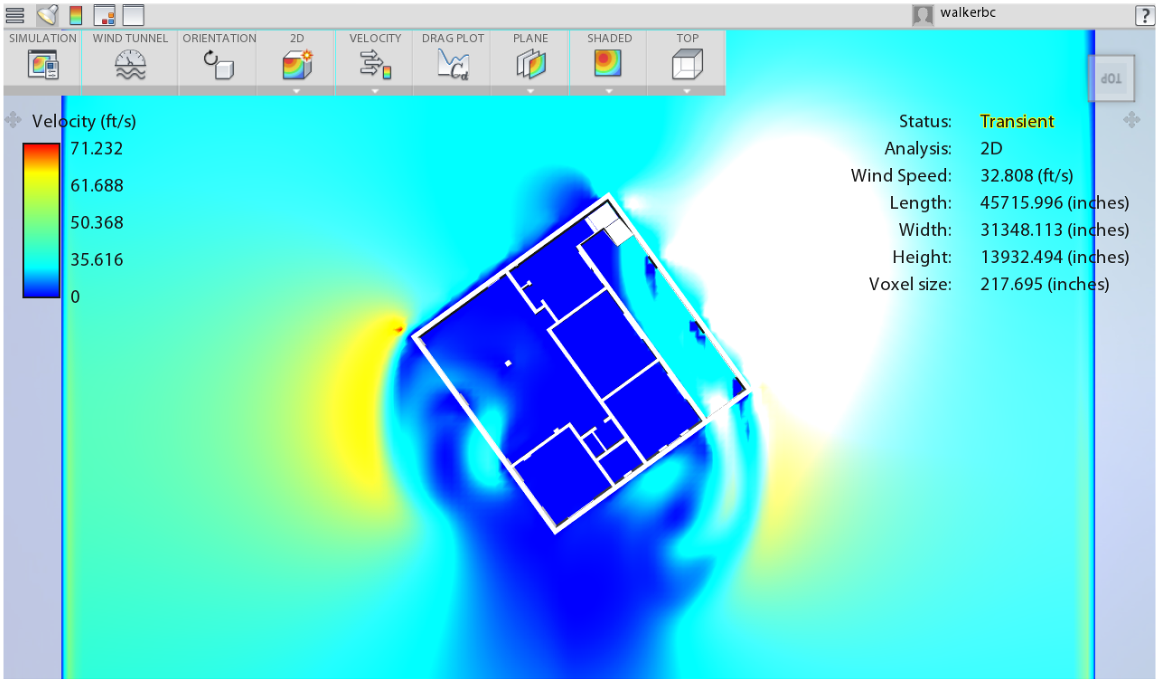

Figure E.1: Plan view of Quarters M, ground floor - Flow Design simulation using shades. Referenced in text, page 126.

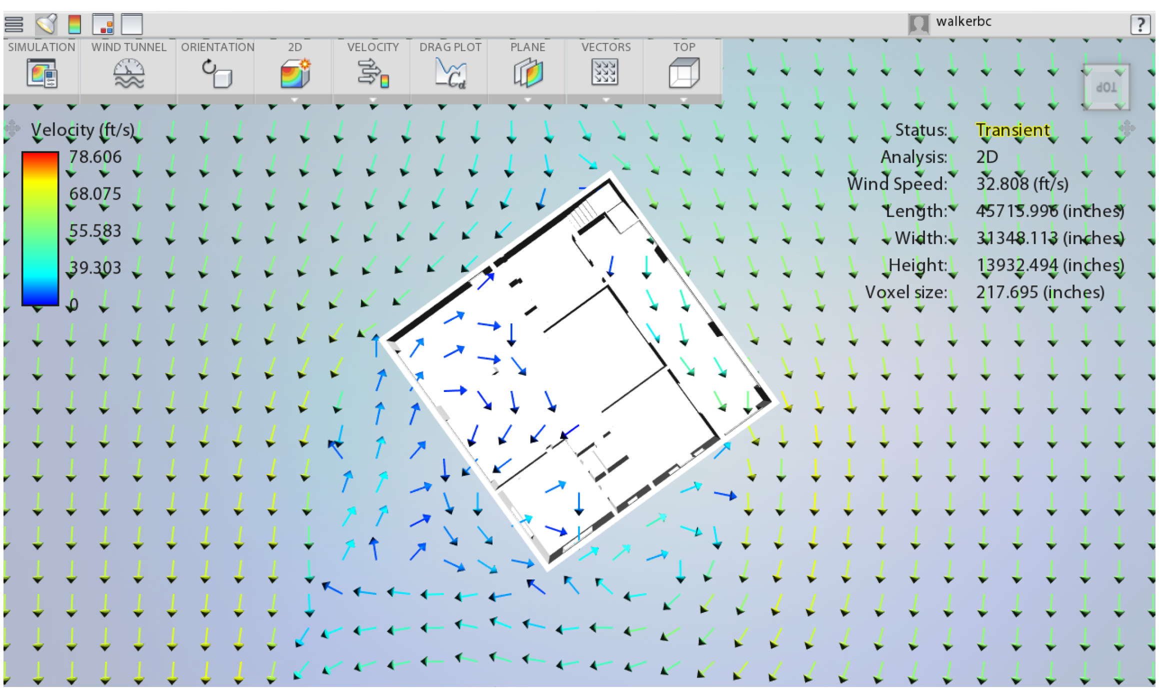

Figure E.2: Plan view of Quarters M, ground floor - Flow Design simulation using vectors. Referenced in text, page 126.

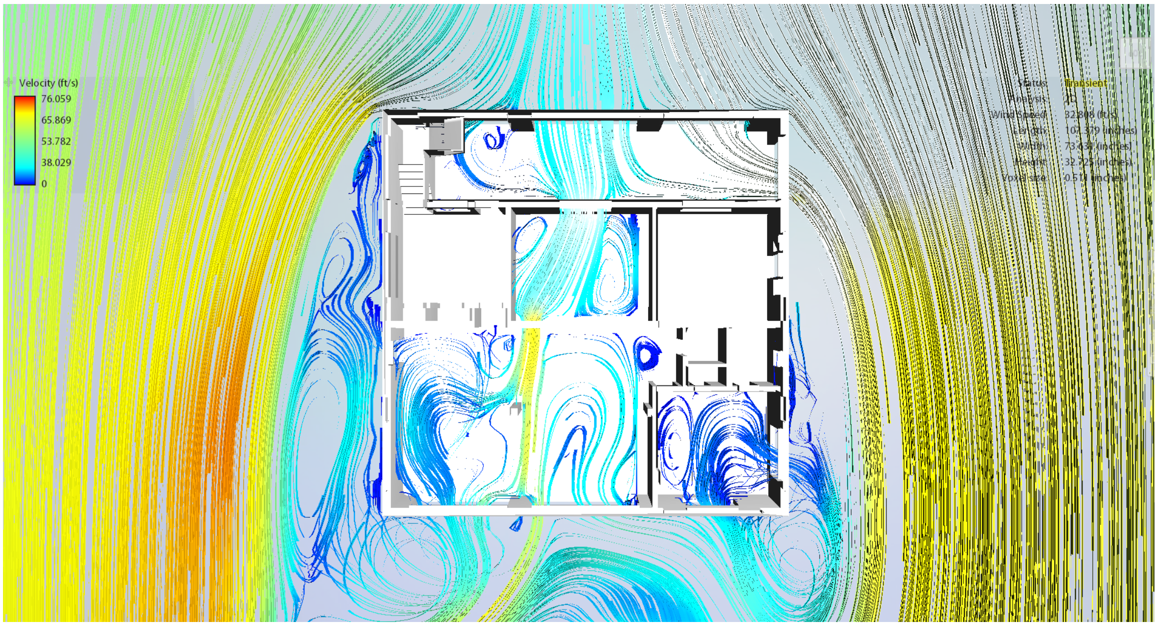

Figure E.3: *Plan view of Quarters M, ground floor - Flow Design simulation using flow lines.* Referenced in text, page 127.

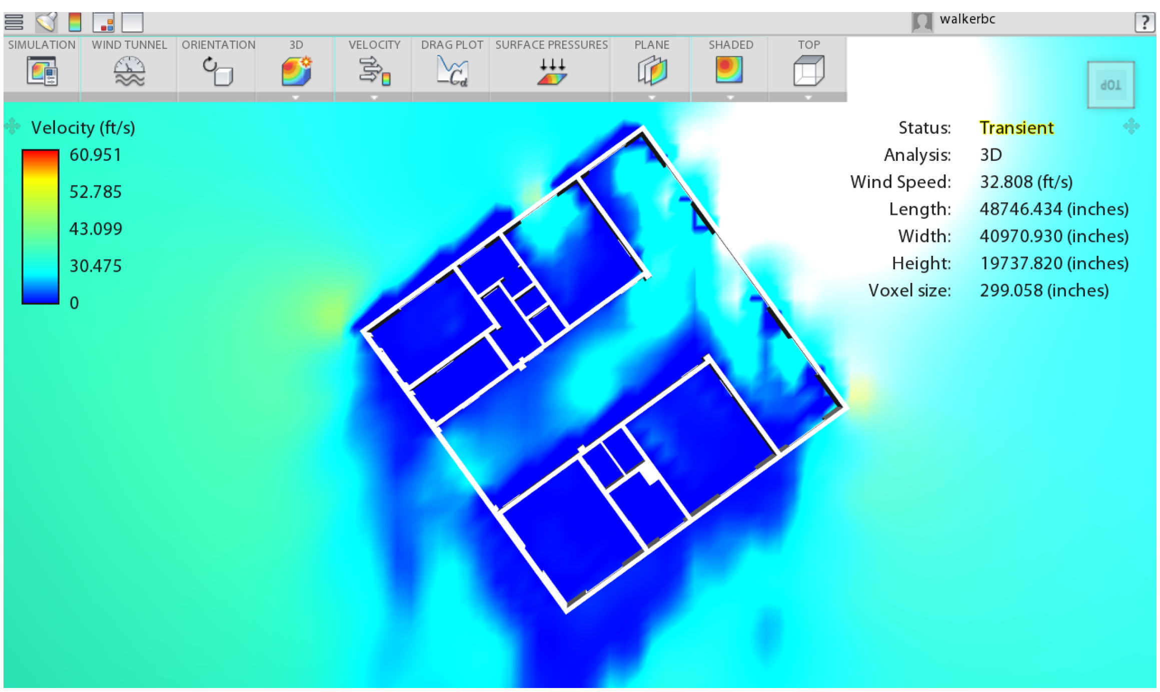

Figure E.4: *Plan view of Quarters M, second floor - Flow Design simulation using shades.* Referenced in text, page 128.

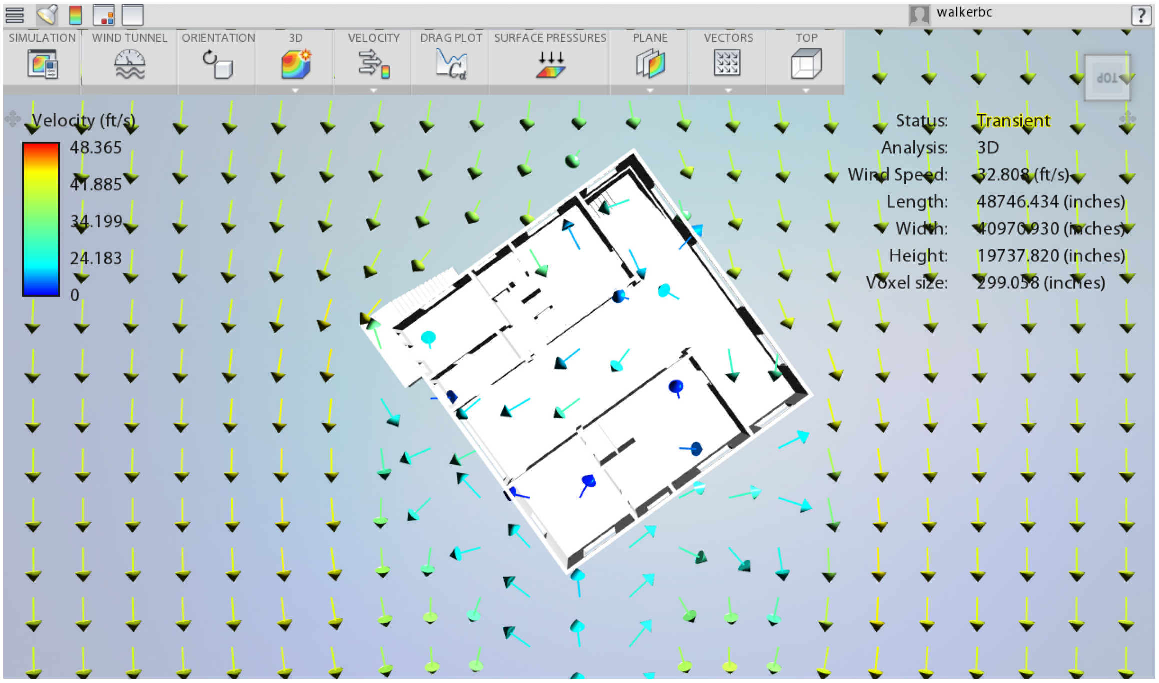

Figure E.5: *Plan view of Quarters M, second floor - Flow Design simulation using vectors.* Referenced in text, page 128.

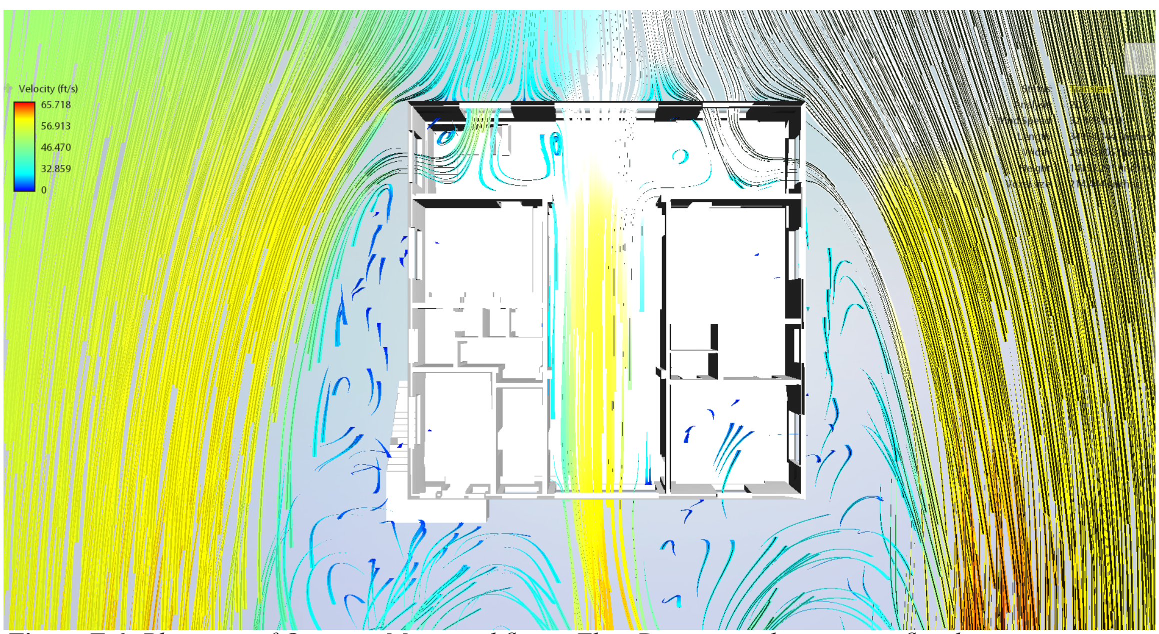

Figure E.6: *Plan view of Quarters M, ground floor - Flow Design simulation using flow lines.*

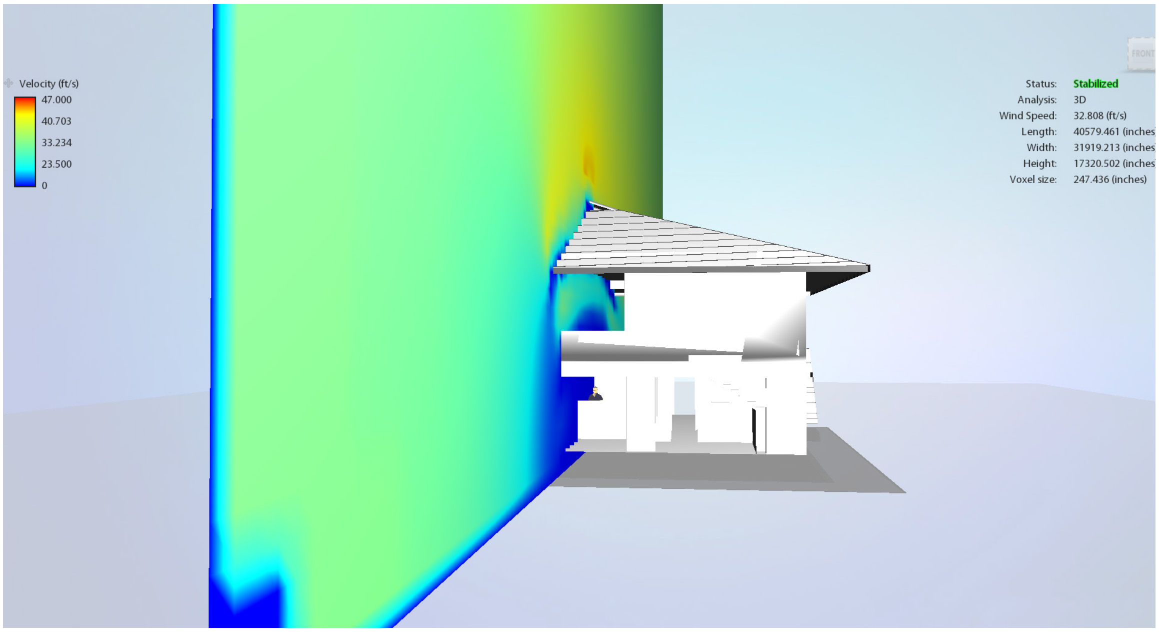

Figure E.7: *Perspective view of Quarters M - Flow Design simulation using vertical shaded plane.* Note the movement of air through the interior of the building by means of cross-ventilation.

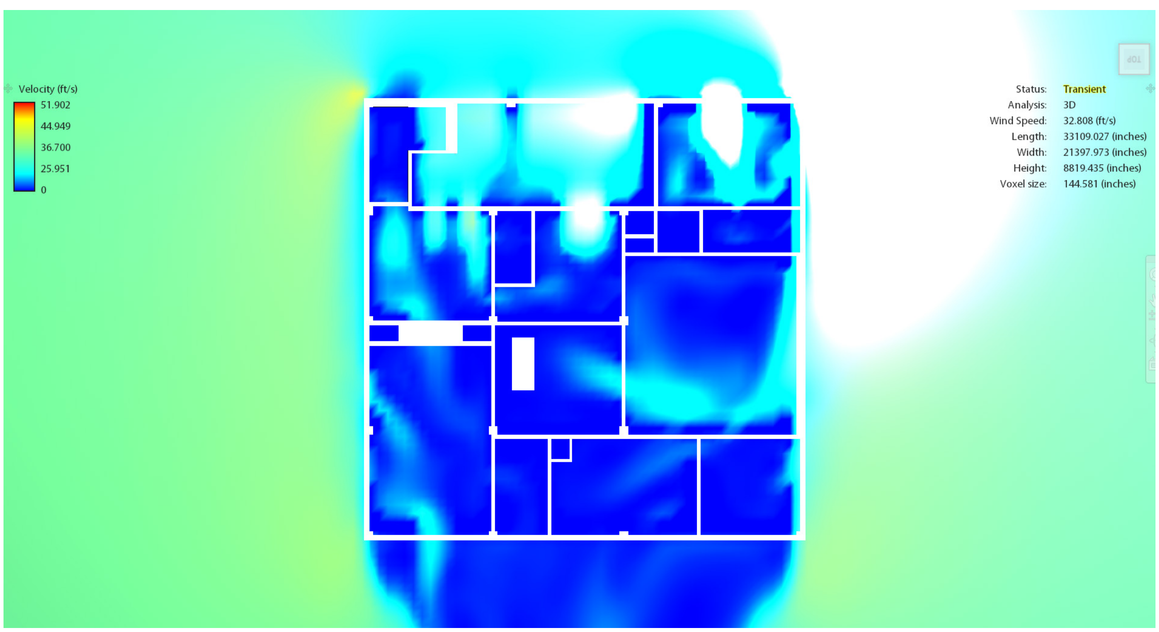

Figure E.8: *Plan view of Quarters T, ground floor - Flow Design simulation using shades.* Referenced in text, page 133.

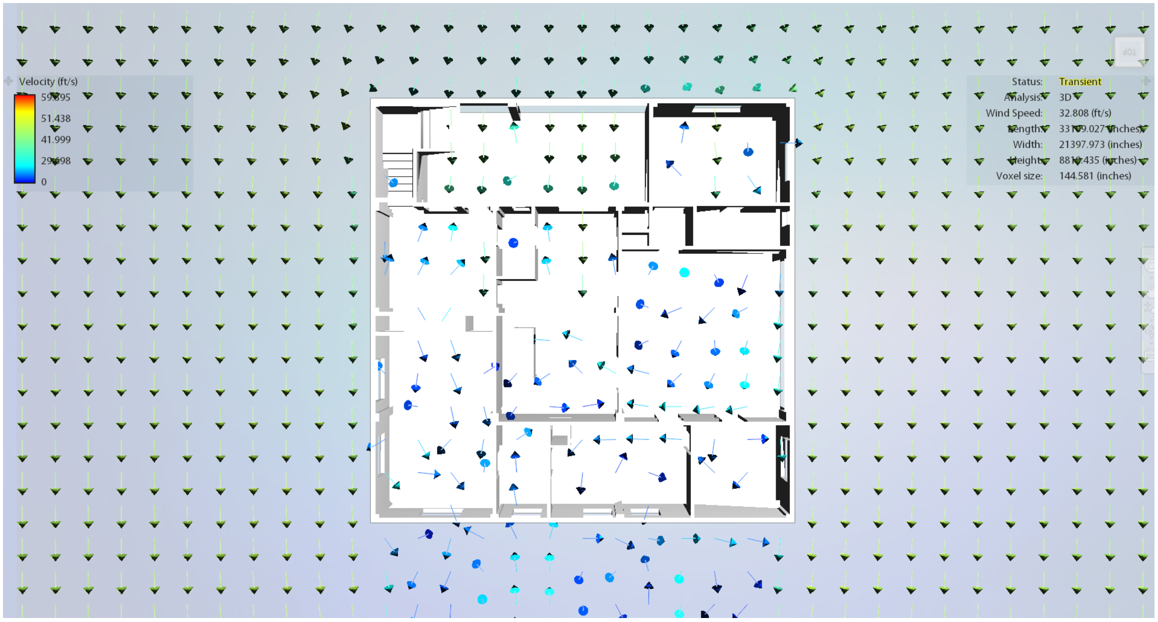

Figure E.9: *Plan view of Quarters T, ground floor - Flow Design simulation using vectors.*

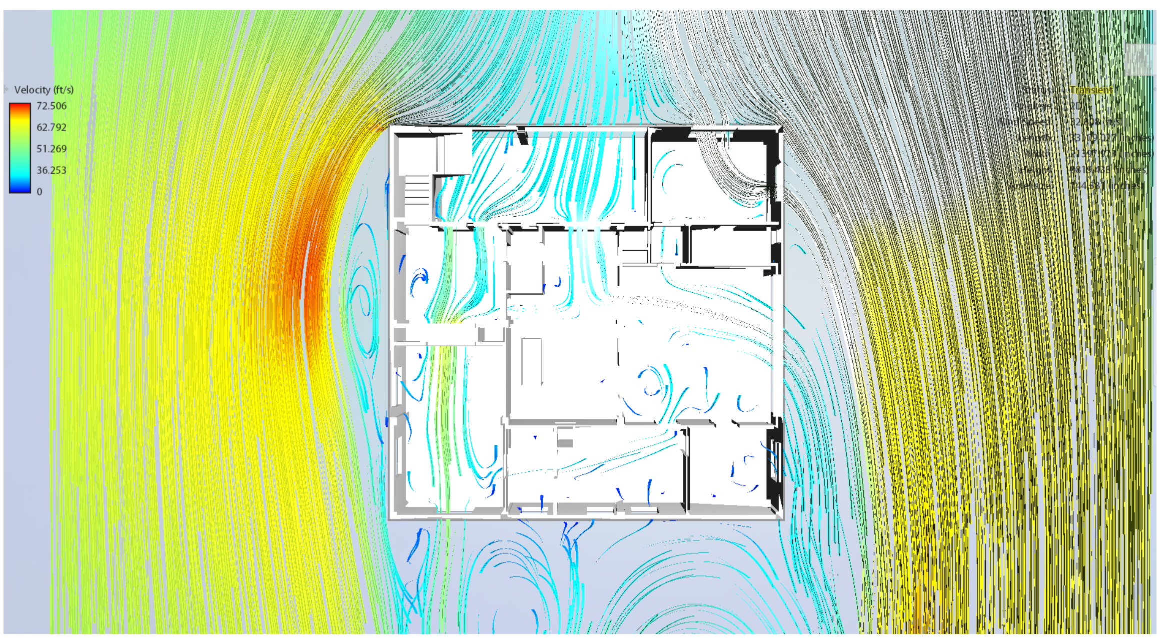

Figure E.10: *Plan view of Quarters T, ground floor - Flow Design simulation using flow lines.* Referenced in text, page 133.

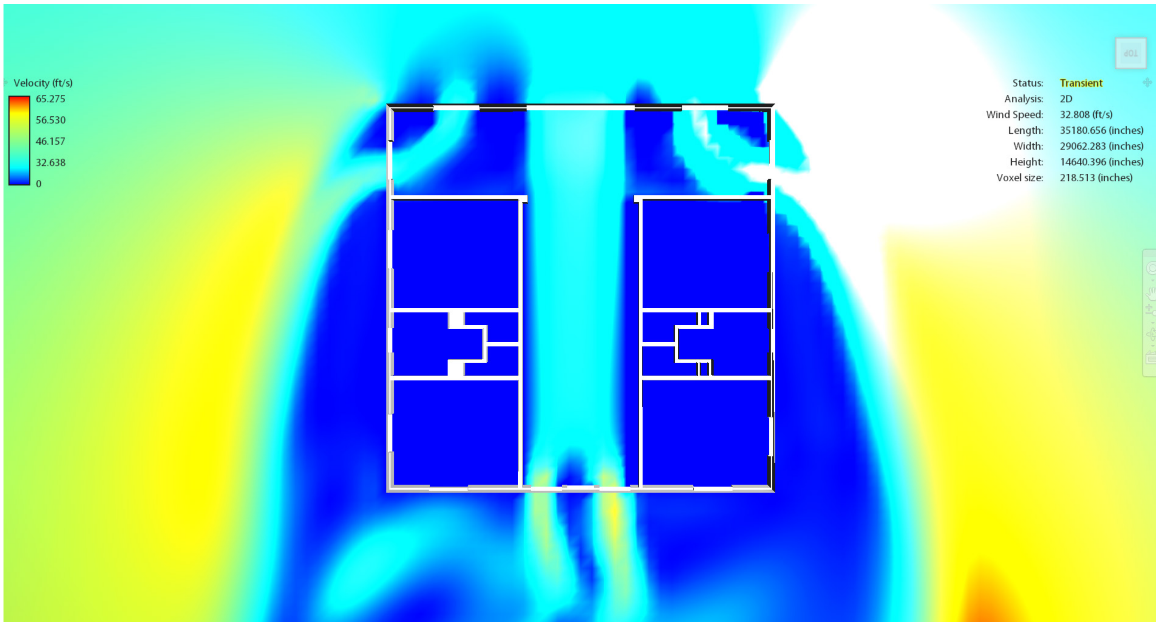

Figure E.11: *Plan view of Quarters T, second floor - Flow Design simulation using shades.* Referenced in text, page 134.

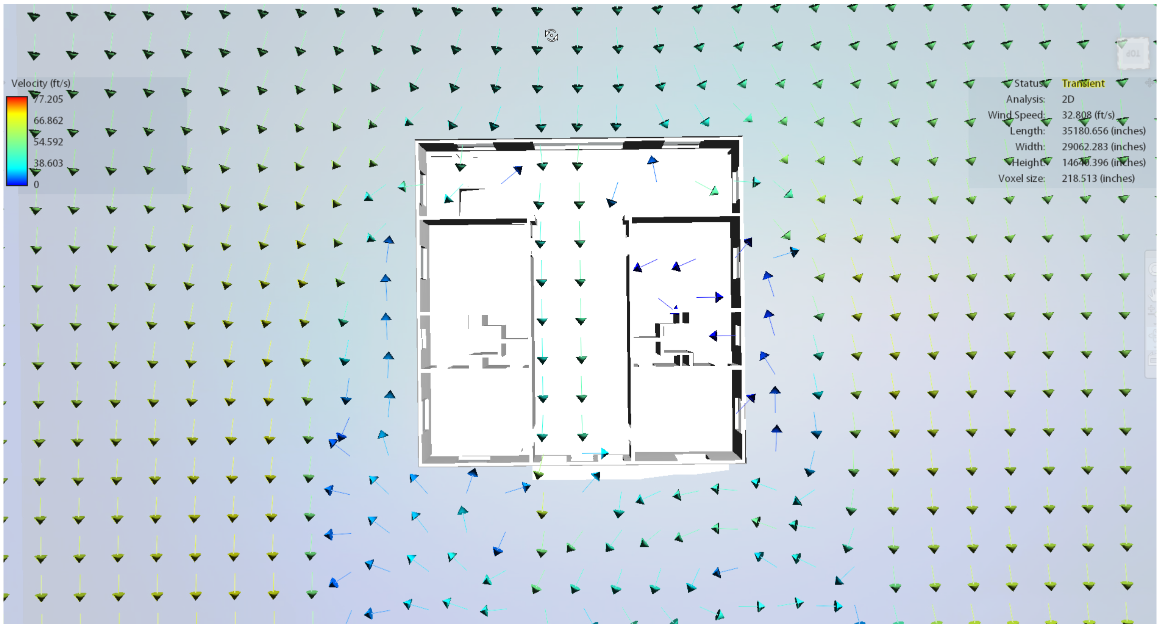

Figure E.12: *Plan view of Quarters T, second floor - Flow Design simulation using vectors.*

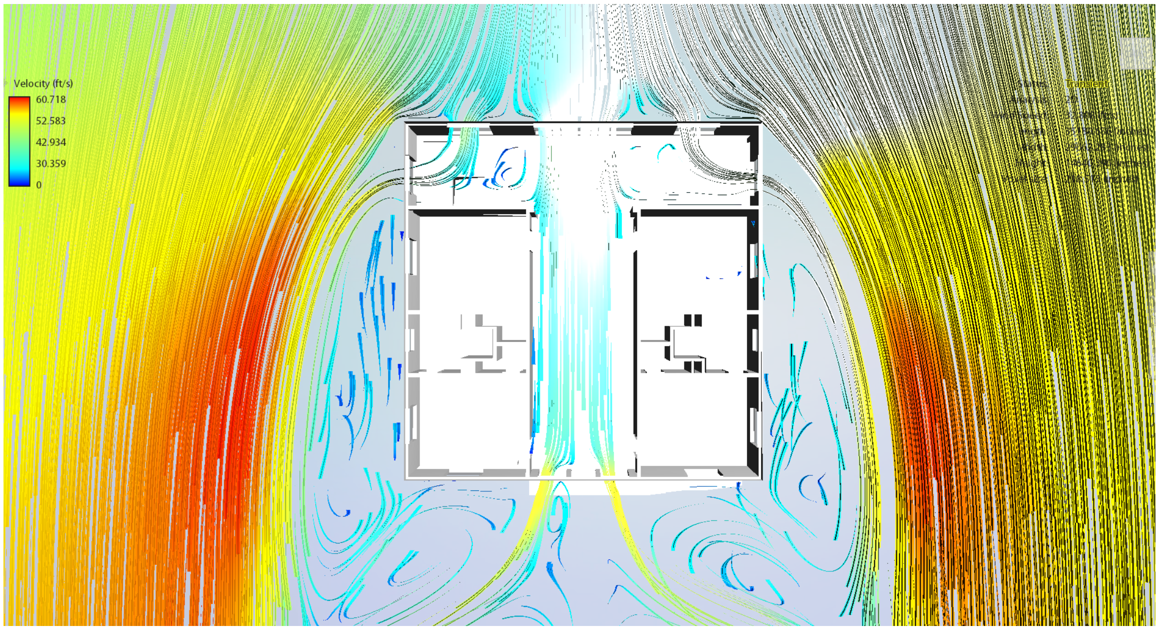

Figure E.13: *Plan view of Quarters T, second floor - Flow Design simulation using flow lines.* Referenced in text, page 134.

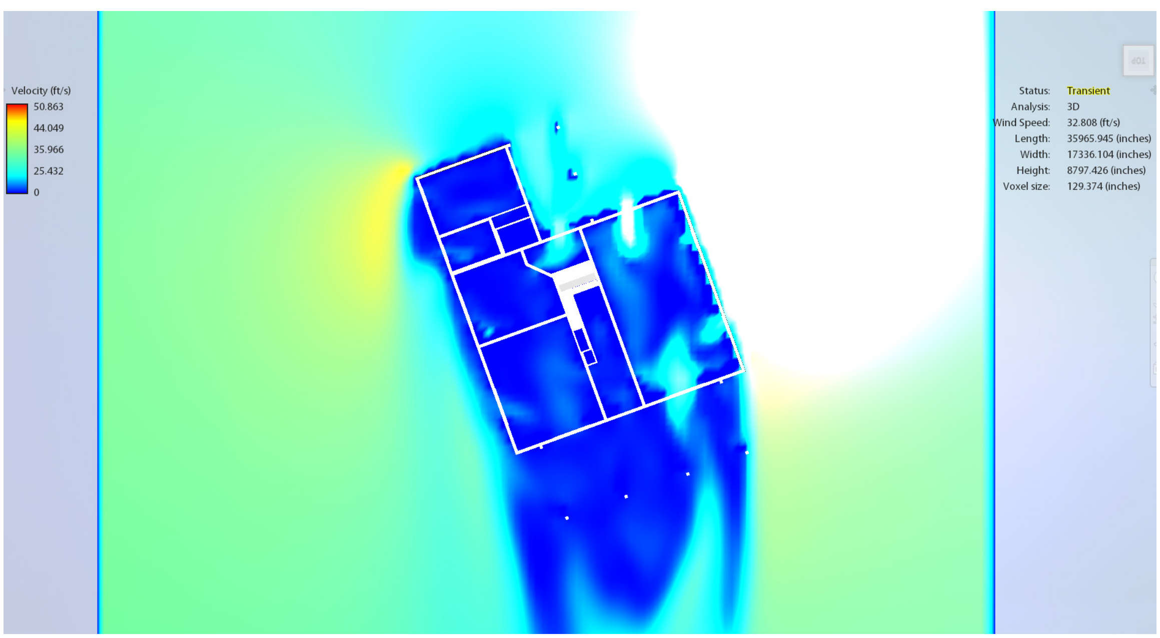

Figure E.14: *Plan view of Quarters X, ground floor - Flow Design simulation using shades.* Referenced in text, page 138.

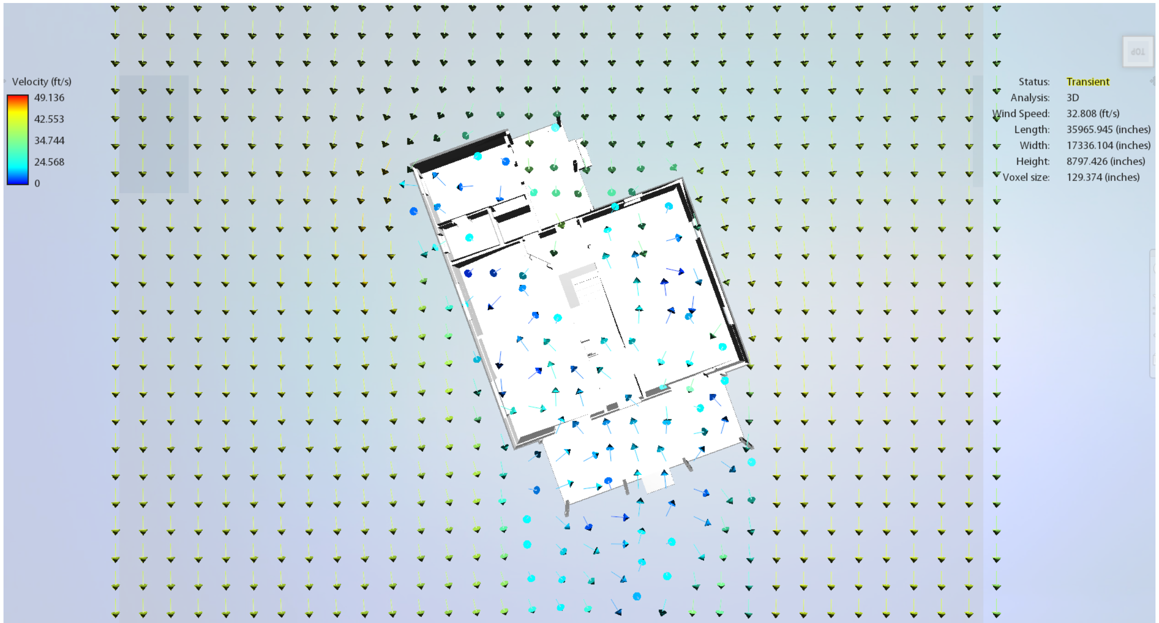

Figure E.15: *Plan view of Quarters X, ground floor - Flow Design simulation using vectors.*

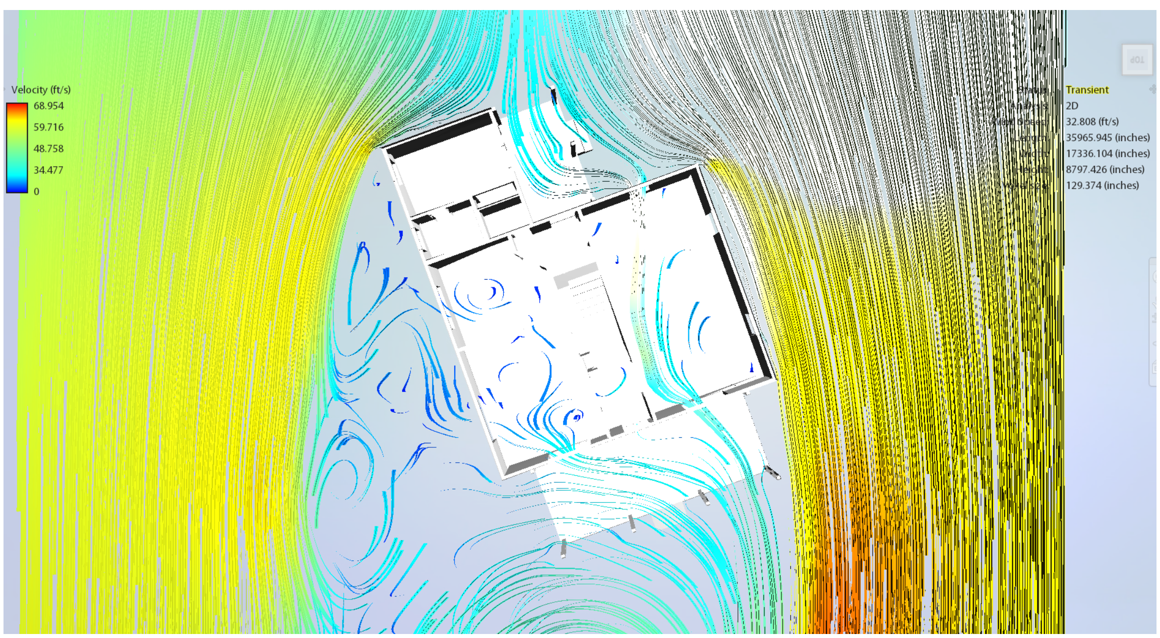

Figure E.16: *Plan view of Quarters X, ground floor - Flow Design simulation using flow lines.* Referenced in text, page 138.

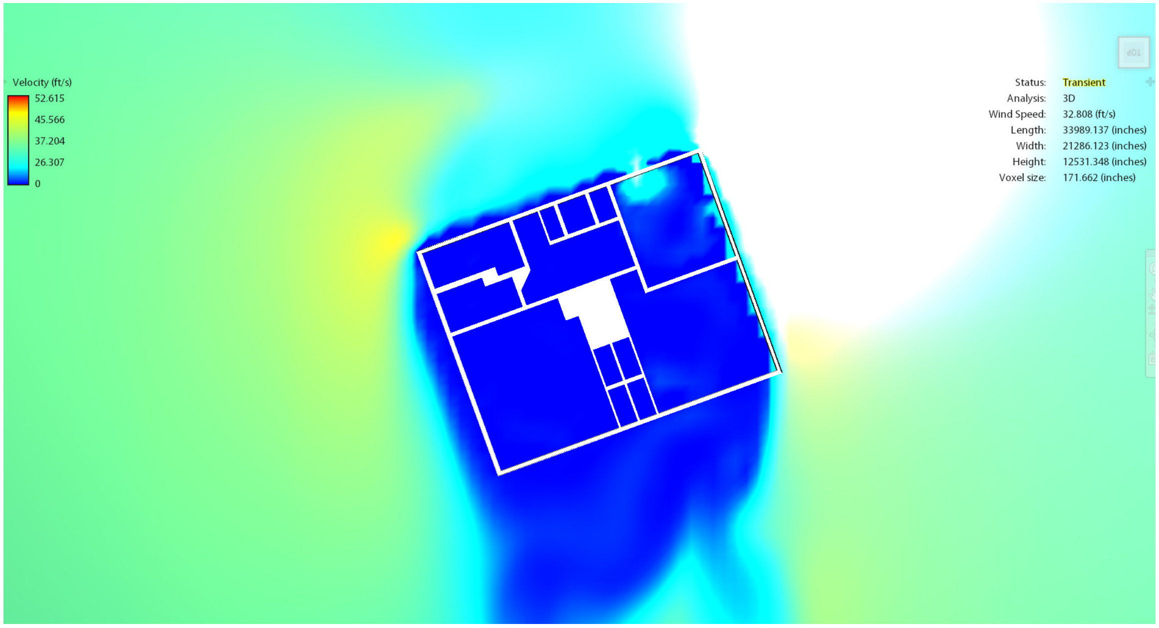

Figure E.17: *Plan view of Quarters X, second floor - Flow Design simulation using shades.* Referenced in text, page 134.

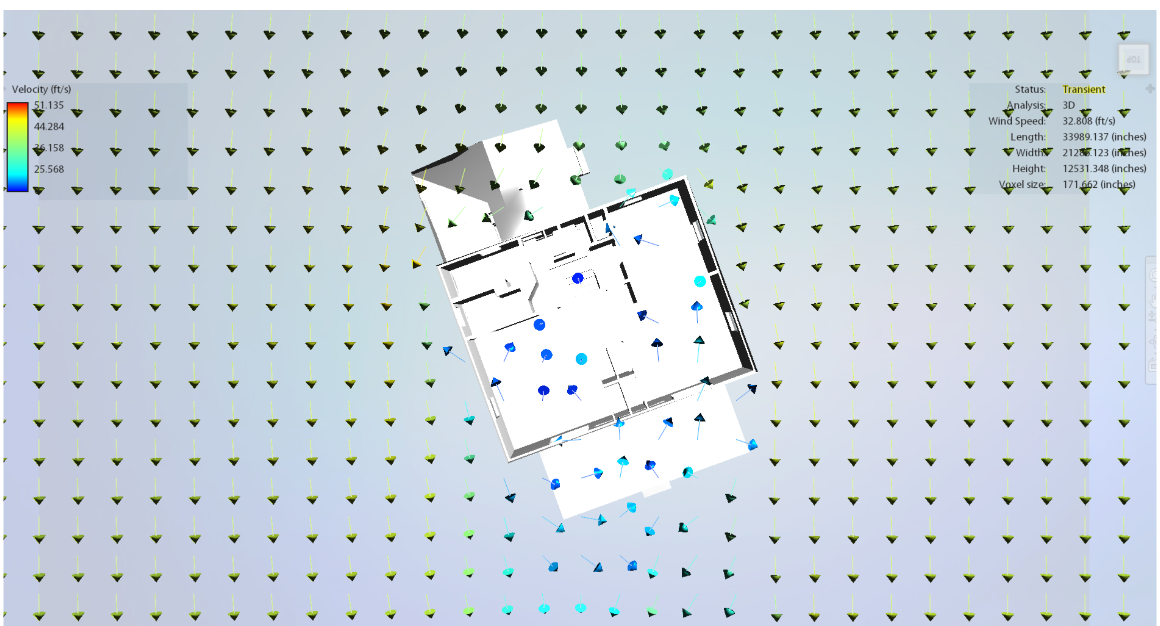

Figure E.18: *Plan view of Quarters X, second floor - Flow Design simulation using vectors.* Referenced in text, page 139.

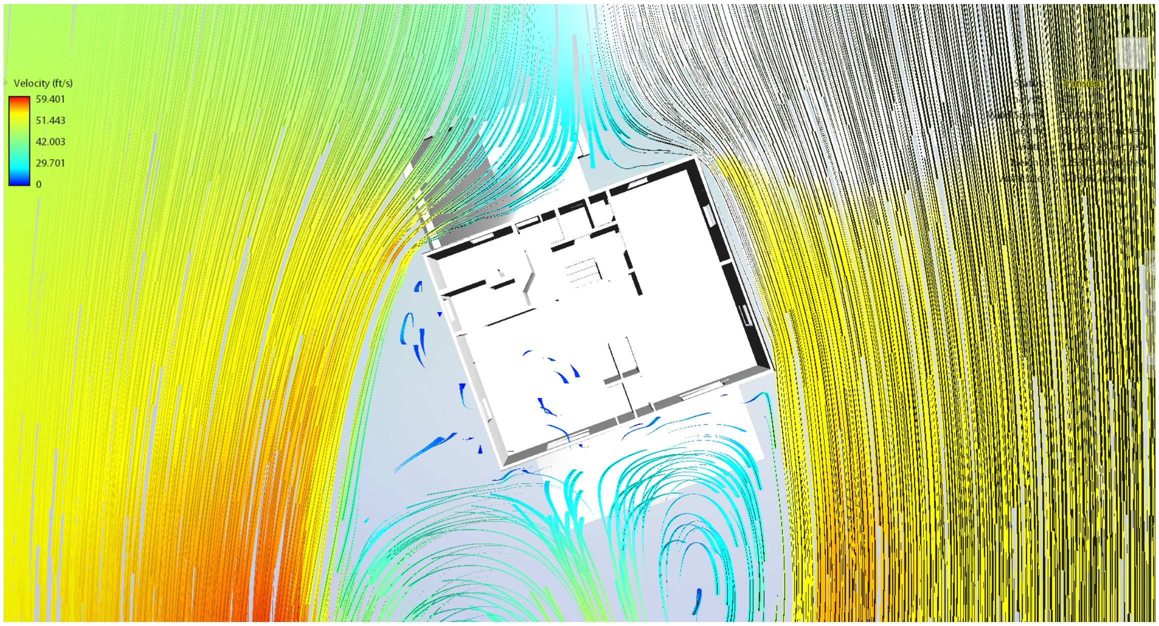

Figure E.19: *Plan view of Quarters X, second floor - Flow Design simulation using flow lines.* Referenced in text, page 139.

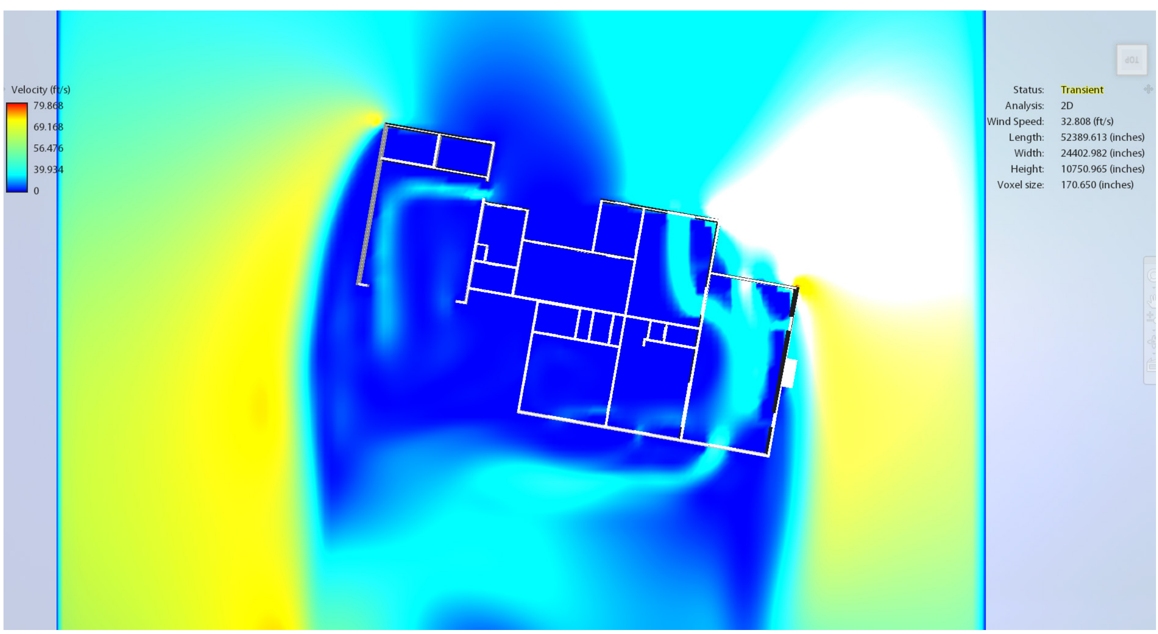

Figure E.20: *Plan view of Quarters Y, ground floor - Flow Design simulation using shades.* Referenced in text, page 144.

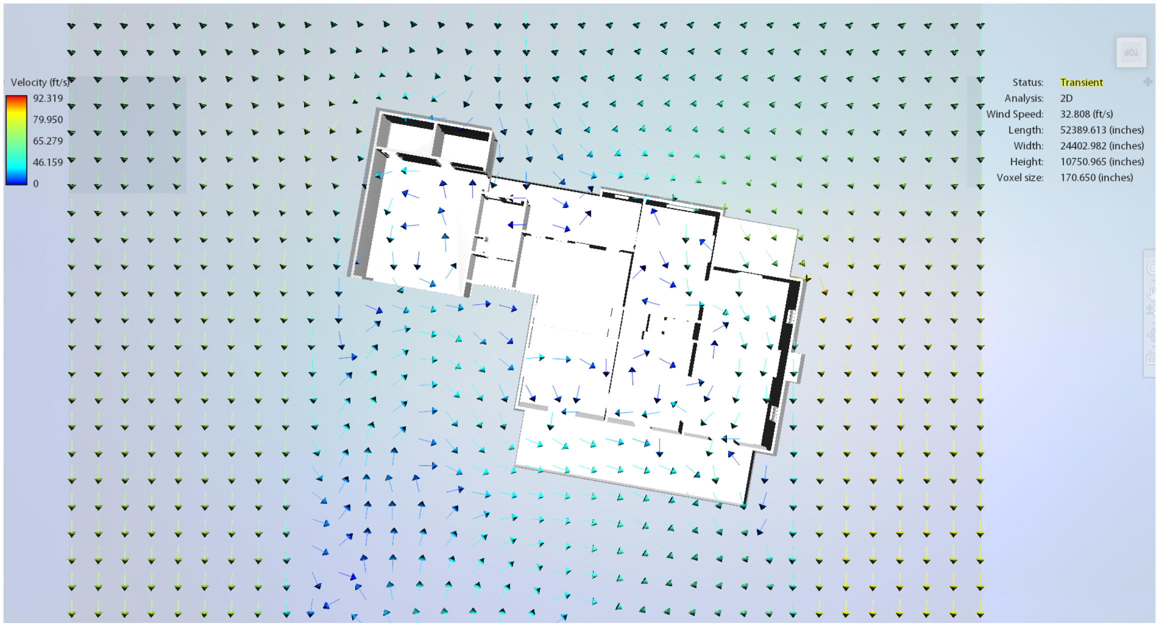

Figure E.21: *Plan view of Quarters Y, ground floor - Flow Design simulation using vectors.*

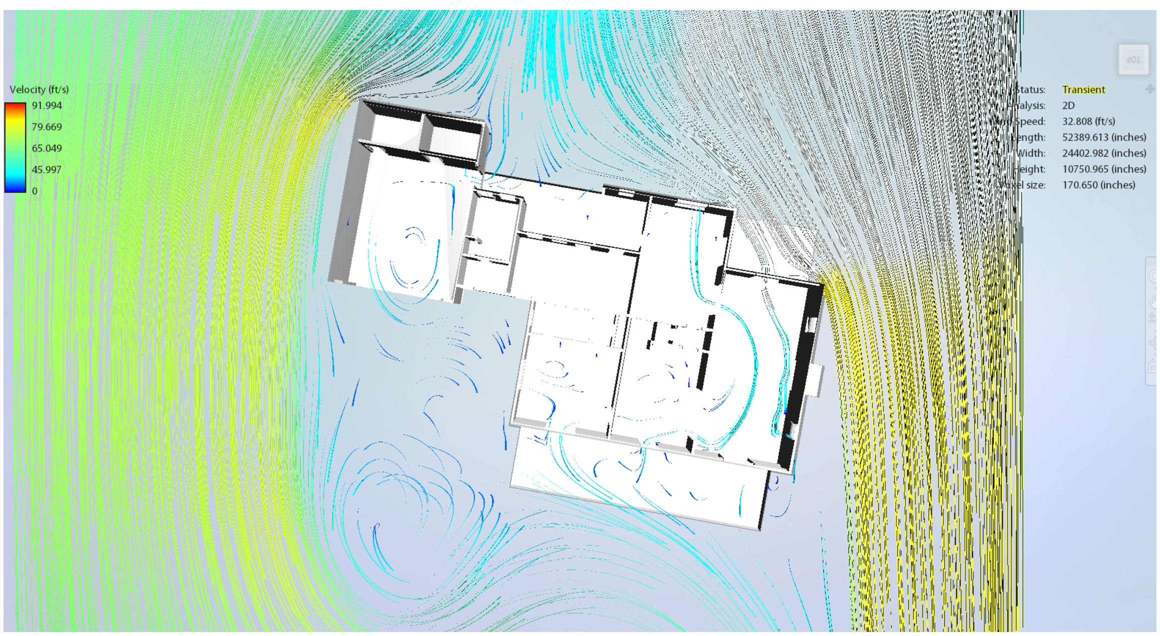

Figure E.22: *Plan view of Quarters Y, ground floor - Flow Design simulation using flow lines.* Referenced in text, page 144.

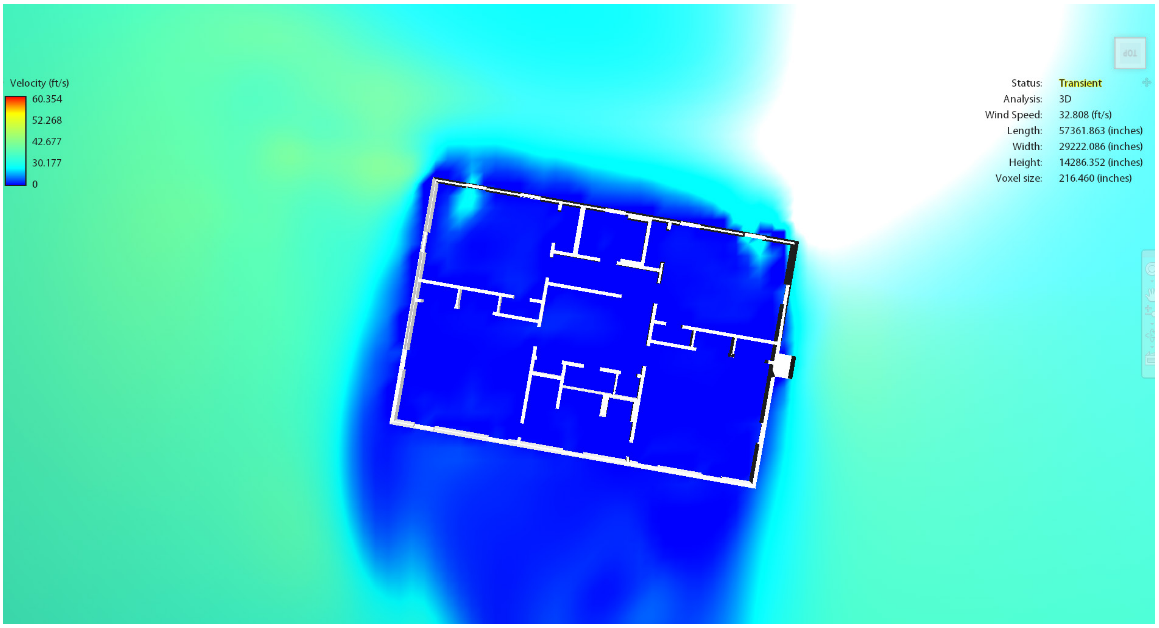

Figure E.23: *Plan view of Quarters Y, second floor - Flow Design simulation using shades.* Referenced in text, page 145.

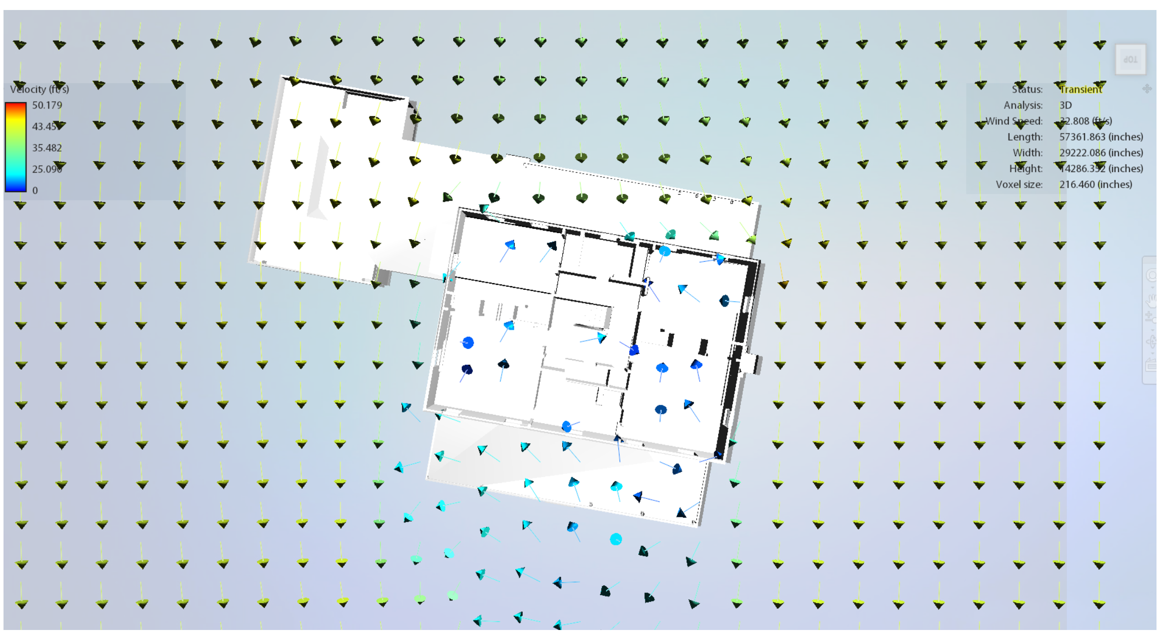

Figure E.24: *Plan view of Quarters X, ground floor - Flow Design simulation using vectors.* Referenced in text, page 145.

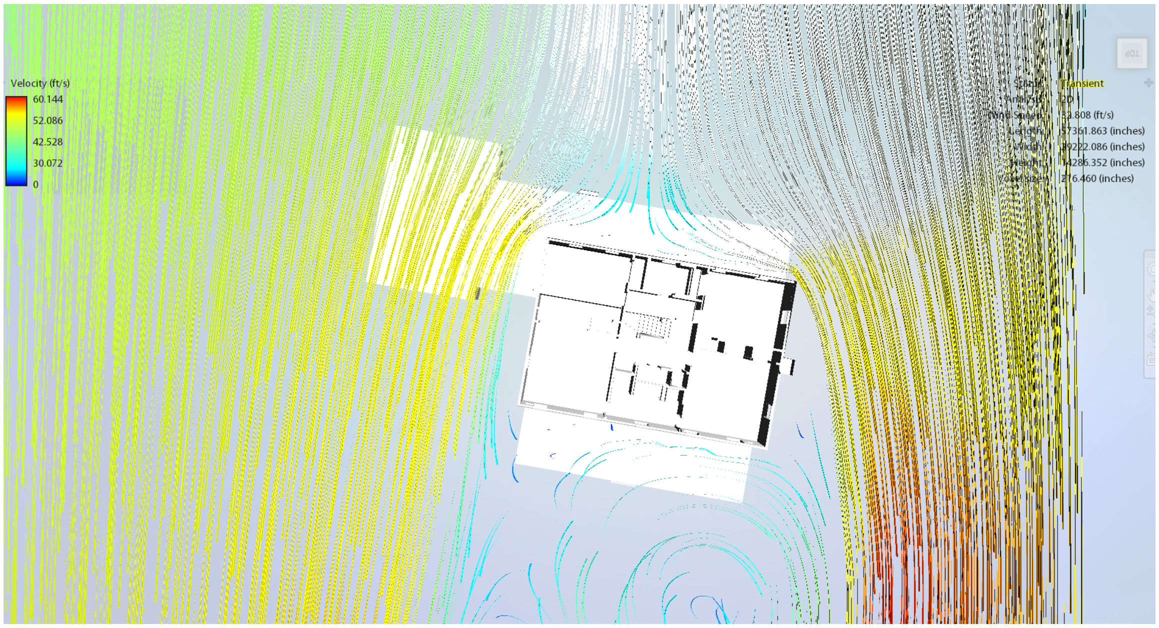

Figure E.25: *Plan view of Quarters Y, second floor - Flow Design simulation using flow lines.*

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